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The New Royal Greenwich Observatory at Herstmonceux

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Steady progress is being made with the removal to Herstmonceux in the English county of Sussex, of the Royal Greenwich Observatory. H. M. King George VI has been pleased to give his assent to this new name, which is a reminder of the long association of the Observatory with the site in the royal park at Greenwich, near London, given by its founder, King Charles II in 1675.

Approaching the stately Herstmonceux Castle, with its beautiful 15th century rose-pink brickwork, there is little at present to remind the visitor that a large observatory is in process of transference to the site. But within the Castle much work has been done to adapt it to the needs of Britain's oldest scientific institution. The interior, entirely modernized within recent years, lends itself well to the purpose of the Observatory. The Great Hall is being converted into the Observatory Library, a reinforced concrete floor will carry the great weight of books, and along one side a gallery has been built to provide additional shelving space; it will make a magnificent library, with ample accommodation for future additions. Some of the large rooms, such as the Long Gallery, which served as a Ball Room, have been subdivided for convenience. The Chapel has been turned into a Conference Room; collo-

HERSTMONCEUX CASTLE, HAILSHAM, SUSSEX, ENGLAND

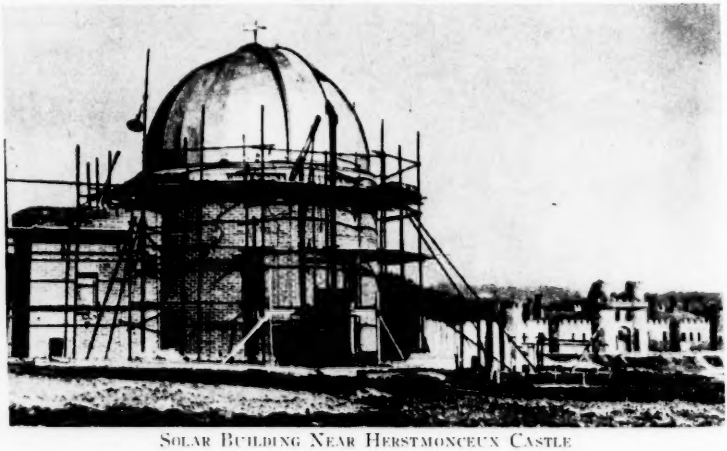
quia will be held in it at regular intervals, which will help to keep the staff in closer touch with new work and developments in astronomy.

A portion of the Castle has been adapted as a self-contained residence for the Astronomer Royal; the rest of it provides office accommodation for the Astronomer Royal, two Chief Assistants, the Secretariat, the Solar Department, the Department of Astrometry and Astrophysics, the Meridian Department, the Magnetic and Meteorological Department, the Chronometer Department, with optical laboratories, photographic laboratory, dark rooms, and the storage of records and photographic plates.

To the south of the Castle there are several temporary buildings which were erected during World War II. These huts will eventually be dismantled. At present they house the Nautical Almanac Office, which was evacuated on the outbreak of war; a full range of punch-card equipment, and a chronometer and watch repair workshop. Others are used for the temporary storage of dismantled instrumental equipment from Greenwich, and of photgraphic records and publications as well as for the hostel accommodation of single staff and as recreation rooms.

Solar Building

At present the only new buliding erected is the solar building, which contains the photoheliograph, two spectrohelioscopes, and underground tunnels for the solar spectrograph and spectroheliograph. The average definition of the solar photographs obtained at Herstmonceux is far superior to that obtained at Greenwich. Not only is there more clear sky and a more transparent atmosphere at Herstmonceux, but also the atmosphere is much more steady. The Solar Department, the Chronometer Department, and the Magnetic and Meteorological Department, in addition to the Nautical Almanac Office, are already installed.



Solar Building Near Herstmonceux Castle

Much detailed planning of the new buildings for housing the telescopes has been in progress. The detailed requirements for each building have been specified, so that the architect has all the information needed for the preparation of design. The telescopes will be divided into groups. To the north-west of the Castle, on top of a ridge from which the ground slopes gently away to north and south, will be installed a group of meridian instruments. It will include the Cooke reversible transit circle from Greenwich, the Melbourne reversible transit circle, which will be used primarily for differential work, the photographic zenith tube (now under construction, but nearing completion), and a Bamberg broken transit instrument. A new pavilion will be erected to house the Cooke transit circle; the pavilion in which it is now housed at Greenwich will then be dismantled and re-erected at Herstmonceux to house the Melbourne transit circle. The site for the meridian group will be free from refraction anomalies and permit the installation of meridian marks both north and south of the instruments. The Airy transit circle, which defines the prime meridian of longitude, is still in use at Greenwich; a century of observations will have been completed with it by the end of 1950. It will remain at Greenwich in position on the prime meridian as an historic instrument with other old instruments, dating from Halley's time.

Modernizing Equipment

The main group of equatorial instruments will be placed on an extensive level site on the top of the higher ground to the east of the Castle. This group will contain three refracting and three reflecting telescopes. The 26-inch photographic refractor and the 28-inch visual refractor, whose domes were badly damaged during World War II, have already been dismantled at Greenwich. The opportunity is being taken of modernizing equipment while it is dismantled. The dome for the 26-inch refractor will be provided with a rising floor. The 13-inch astrographic refractor is still in place at Greenwich and has been in use for experiments on methods of photo-electric guiding.

The 30-inch reflector was mounted at Greenwich on the same mounting as the 26-inch refractor, to which it served as a counter-poise. The arrangement was inconvenient, because both telescopes could not be in use at the same time. The 30-inch reflector will be provided with a separate mounting and dome; the mirror, which was slightly astigmatic, has been refigured by Mr. F. J. Hargreaves. The 36-inch reflector will not be dismantled until near the time for its re-erection at Herstmonceux. The third reflector will be a new instrument, a Schmidt telescope of approximately 23-25 inches aperture, provided with an objective prism. The three reflectors will be interconnected to form a single long building with laboratories, dark rooms, plate standardizing room, aluminizing room, plate storage rooms, and offices, the 36-inch reflector being in the center. The 30-inch and 36-inch reflectors will be mounted at the same level, so that they can see into each other; it

will be possible to feed either of them from the other with a nearly parallel full-aperture beam for calibration work. A raised roof between them will allow full-aperture screens to be erected if desired and will give considerable freedom for a wide range of tests and operations.

Isaac Newton Reflector

The Isaac Newton reflector will stand by itself to the south of the main equatorial group and will be the last instrument to be installed. The optical design has been settled and the 98-inch glass disk, the gift of the Trustees of the McGregor Fund of Detroit, is now at the works of Sir Howard Grubb, Parsons and Co., Newcastle-on-Tyne in the north of England, where the rough grinding has been begun. The mirror will be given a spherical figure, with a radius of curvature of approximately 588 inches. A Schmidt correcting plate, with clear aperture of 85 inches, will be provided for direct photography and for nebular spectroscopy at the prime focus. Aspherical Gregorian secondary mirrors will be used for spectrographic observations at the Cassegrain and Coudé foci, the correcting plate being dismounted for these observations. A Board of Management, of which I, as Astronomer Royal, am Chairman, is dealing with the design of the instrument. Committees of the Board are considering the details of servo-controls and photo-electric methods of guiding, of spectrograph design, and of the mechanical design.

A large building is projected to house the Nautical Almanac Office and the Time Department. Early in World War II the Time Department was removed from Greenwich to Abinger, in the English county of Surrey, where the Magnetic Observatory is situated; the main section has remained there while a subsidiary section was brought into operation at Greenwich after the end of the war. The whole of the quartz clock equipment, all the ancillary electronic equipment, the various aerials for the reception of foreign time signals, and the electronic laboratories will be moved to Herstmonceux. The longitude of Abinger is known with great accuracy from the several years of simultaneous time determinations at Greenwich and Abinger. Before all equipment is finally removed from Greenwich, it will be necessary to determine the longitude of Herstmonceux with high accuracy; simultaneous observations at Herstmonceux, Abinger, and Greenwich will be used for this purpose. The time distributed from Herstmonceux will continue, of course, to be Greenwich Mean Time, the appropriate correction for the longitude of Herstmonceux (about 0° 21′ E) being made.

An essential requirement for any observatory is a good work shop. The building planned for this will also serve as the chronometer and watch repair shop.

The target date which has been set for the completion of the move is the end of 1953, but the Isaac Newton Telescope is unlikely to be completed and ready for use before 1955 or 1956. The transitional period, during which staff and equipment are divided between Herst-

monceux, Abinger, and Greenwich, is necessarily one of considerable difficulty. While instruments are dismantled and new buildings and domes to house them are under design and construction, observations are interrupted so that for a few years the observational output of the Observatory must be on a reduced scale. But when the move has been completed, the Royal Greenwich Observatory will enter upon a new lease of life and will once again make an effective contribution towards the advancement of astronomy.

The Discovery and Exploitation of Spectroscopic Parallaxes

By DORRIT HOFFLEIT

(Continued from page 438)

Hertzsprung's Fundamental Investigations

Miss Maury's work on spectral classification was begun in 1888 and her catalogue of bright stars was published in 1897 (*H. A.*, **28**). Yet it was eight years before the significance of Miss Maury's divisions and remarks was first clearly appreciated—by Ejnar Hertzsprung in 1905. In the *Zeitschrift für wissenschaftliche Photographie* (Band III, 429, 1905) he called attention to her remark, that stars of division *c* must differ in constitution from those of divisions *a* and *b*, which presumably belong to collateral evolutionary series. If this means that all stars do not follow the same spectral development, what is the fundamental difference between them: mass, composition, or other characteristic? In order to investigate this question, Hertzsprung made use of available proper-motion, radial velocity, and parallax data as well as of color indices.

In the three papers on this subject that Hertzsprung published between 1905 and 1909 (*Zeitschrift für wissenschaftliche Photographie*, III, 429, 1905; V, 86, 1907; and *A. N.*, **179**, 373, 1909), he laid the foundation for what subsequently became known as the Russell-Diagram and later the Russell-Hertzsprung or Hertzsprung-Russell-diagram. Hertzsprung himself never actually published such a diagram. The data available to him on individual stars gave absolute-magnitude spectral-class results that would hardly have been considered convincing evidence for the existence of the two discrete sequences which he succeeded in differentiating so accurately through more inductive reasoning based on stellar motions and double-star data. His classical paper of 1905, "Zur Strahlung der Sterne" deals with the following comprehensive outline:

1. Available proper motions reduced to $m = 0$ separately for *c*-stars and others.

2. Apparent magnitudes, m, reduced to $\mu = 0''.01$ per century for non-c-stars.
3. Color equivalents and the possibility of extinction in c-stars.
4. Radial velocities (only 60 available).
5. Trigonometric parallaxes reduced to $m = 0$.
6. The spectra of components of double stars.
7. The masses of double stars.

Principal emphasis in this paper is given to the distinction between the c-stars and the others. The data Hertzsprung assembled are for the most part not the coordinates of a Russell-Diagram. Instead of having reduced the data to a common stellar distance, Hertzsprung reduced most of them to a common apparent magnitude, from which the progression of luminosity was inferred—qualitatively rather than quantitatively. No absolute magnitudes as such were recorded in this first paper. He did, however, give mean values corresponding to our H-values, from proper motions reduced to 0".01 per century for the run of the stars, but exclusive of c-stars. In treating the trigonometric parallaxes, Hertzsprung included only stars brighter than Harvard visual magnitude 3.005. Most of the fainter stars for which trigonometric parallaxes were then available would have been put on parallax observing programs primarily because of their previously known exceptionally large proper motions. Their inclusion in his analysis, Hertzsprung pointed out, would have been apt to introduce systematic errors into the resulting relation between spectral class and absolute magnitude.

Numerous significant conclusions were reached. Among the c-stars only small values of proper motion (reduced to $m = 0$) occurred in comparison with the values corresponding to the a and b spectral divisions. This would indicate great distances for the c-stars, a fact confirmed by their known tendency to lie closer to the Milky Way than do the stars of the other divisions. The c-characteristic was noted to become less pronounced with later spectral class and to vanish just where luminous K-type stars set in. The reduced parallaxes, while they were not yet numerous, already showed that the maximum value (corresponding to $m = 0$) occurs for the neighborhood of type G. The double stars in general were found to have smaller proper motions than single stars having the same spectral class as that of the principal component; but in the case of α Centauri, where the fainter star is the redder, the general rule does not hold. Finally, the most relevant result was that, among stars brighter than the fifth apparent magnitude, the c-stars and the "Orion" types are the most luminous, while among the rest it is not the red stars but the yellow ones that are the least luminous. The hypothesis of two collateral (evolutionary) series would account for this. Hertzsprung gave a list (Table II) of the stars representative of the two sequences. He listed only the names or typical groups of the stars in their proper sequence; in Table II more recent data from other

TABLE II

HERTZSPRUNG'S TWO SEQUENCES

First Sequence	Maury Class	Maury Rem.	HD	Mt. W.* M	Mt. W.* Sp	Trig. π	Trig. M_v	Second Sequence	Maury Class	Maury Rem.	HD	Mt. W.* M	Mt. W.* Sp	Trig. π	Trig. M_v
Nebulae								Nebulae							
S Mon	IIb	1	Oe5			".006	!	χ_2 Ori	IIIc		B2p				
ϵ Ori	IIa		B0			—.006	!	β Ori	VIc		B8p			".006	—5.8
γ Ori	IVa		B2			.017	—2.2	α Cyg	VIIIc		A2p			—.007	!
α Leo	VIb		B8			.041	—0.6	δ CMa	XIIIc		F8p	—3.8	eG3	—.019	!
α CMa	VIIa	39	A0	1.2	A2s	.375	1.3	α Boo	XVa		K0	0.2	K0	.085	—0.2
α Aql	Xb	180	A5	2.3	A1n	.208	2.5	α Ori	XVIIIa	128	Ma	—4.0	M2	.011	—3.9
α CMi	XIIa		F5	3.1	F3	.291	2.8	Vogel Type IV			N?				
Sun	XIV		G0												
70 Oph	XVa	112, 184	K0	5.9	K1	.196	5.6								
61 Cyg	XVIa	124	K5	7.7	K6	.299	8.0								
o_2 Eri Br.			G5	6.0	K0	.202	6.0								
"Black Stars"															

*Mt. W. Contr., 511.

NOTES TO TABLE II—MAURY REMARKS

S Mon. (1)—The lines of hydrogen are exceedingly wide.

α Canis Maj. (39)—The lines of this star are not so narrow and sharply defined as those of the other typical star† of Division *a* in this group.

α Aquilae (180)—The line K and the line Hδ are approximately equal.

70 Oph. (112,184)—The line 4227.0 appears somewhat stronger than in α Boötis. This star resembles α Boötis in the absorption shown in the region having wave length shorter than 4307, and in the absence of increased brightness between the lines 4227.0 and 4215.7. See page 39 of Detailed Description.*

61 Cyg. (124)—The spectrum appears as though a faint star of the first type were superposed. This may perhaps be due to the adjacent star.

α Orion—The lines of hydrogen and the line 4227.0 have an intensity similar to that seen in the preceding group. A similar increase in the intensity of the hydrogen lines and diminution in the width of 4227.0 are seen in stars having composite spectra.

†α Lyrae.

*The stars of this group (XV) appear to fall into two divisions, exhibiting a slight difference in the degree of general absorption in the violet region. Of these divisions α Bootis and α Cassiopeiae are, respectively, typical. In the first, the general absorption is slight; in the second, it is more conspicuous, both in the regions of the violet above mentioned and beyond wave length 3889, where the photographic spectrum generally appears to be suddenly cut off. In the latter class of stars, also, the spectrum between lines 4215.7 and 4227.0 generally appears brighter. Frequently also the lines 4227.0 (except in α Cassiopeiae), 4215.7, and the compound line 4076.8 to 4077.9 seem stronger, but this difference may be due to accidental photographic conditions. The degree of absorption indicated also varies in photographs of different density, so that while there seems to be sufficient ground for believing that the distinction is a real one, there is more or less liability to error in assigning individual stars to one or the other division.

sources have been added. The first of the two sequences contains only stars belonging to the main sequence and is well defined. The second sequence contains primarily supergiant stars, with the exception of *a* Boötis. "Vogel's Type IV" is the second sequence presumably refers to Secchi's type IV or Vogel's IIIb, since Vogel did not use "Type IV" in his system of classification. These stars would be the N and possibly R types of the Draper system. All the N-stars for which parallax data are available are supergiants.

The year following this fundamental contribution, A. Pannekoek (*Koninklijke Akademie van Wetenschappen te Amsterdam,* Proceedings of Meeting of June 30, 1906) strengthened Hertzsprung's conclusions by further analysis. He considered the parallactic motion,

$$q = \frac{\Sigma\, v \sin \lambda}{\Sigma \sin^2 \lambda},$$

a better measure of the mean distance of a group of stars than the reduced total proper motions. Since, however, the purpose of his investigation was to derive conclusions about the brightness, and as both the magnitude and the proper motion depend on the distance, the computation was made after reduction to a common apparent magnitude, $4^m.0$. Then the reduced mean parallactic (q) and peculiar motions (τ) are

$$q_{4.0} = \frac{\Sigma\, p\, v \sin \lambda}{\Sigma \sin^2 \lambda} \quad \text{and} \quad \tau_{4.0} = \frac{\Sigma\, p\, \tau}{n}$$

where $p = 10^{0.2(m-4)}$. Pannekoek's results are given in Table III. From

TABLE III

Spectrum		Typical					L for	
Maury	Cannon	Star	n	$\pi_{4.0}$	$q_{4.0}$	$\pi_{4.0}$	$q = 0''.10$	$2\pi/q$
I-III	B	ϵ Orionis	32	0".005	0".014	0".0033	51	0.8
IV-V	B-A	γ Orionis	45	0.013	0.036	0.0086	7.7	0.7
VI-VIII	A	Sirius	87	0.040	0.063	0.015	2.5	1.3
IX-XII	F	Procyon	86	0.101	0.141	0.034	0.50	1.4
XIII-XIV	G	Capella	59	0.182	0.224	0.053	0.20	1.6
XV	K	Arcturus	101	0.120	0.096	0.023	1.1	2.5
XVI-XX	M	Betelgeuze	61	0.050	0.061	0.015	2.7	1.6

Pannekoek, A.: "The luminosity of stars of different types of spectrum": *Koninklijke Akademie van Wetenschappen te Amsterdam.* Proceedings of the Meeting of Saturday, June 30, 1906, p. 140.

the last column he concluded that the linear velocities of all stars are not equal, but that the early types are the slowest and the "Arcturian stars" move the fastest, a conclusion in agreement with the difference between the radial velocities (corrected for solar motion) found by Campbell for the mean of all stars and the much smaller velocities found by Frost and Adams for "Orion-type" stars. Pannekoek's table confirms Hertzsprung's conclusion that the F and G stars are on the average the faintest, not the K and M. He refutes a previous conclusion by Monck that the luminous redder stars have "greater radiating power" as contrary to physical laws, and finds as the only acceptable explanation, that the K and M stars "possess on an average a much larger surface and volume" than the F and G stars. Pannekoek was puzzled in regard to the masses of the late type stars. Because they are cool, it seemed natural to assume that they were in a stage of high condensation. Hence, for their larger volumes they should have much larger masses than the F's and G's, a surprising conclusion in view of their higher linear velocities. On the other hand, if the greater mass for the red stars should not be confirmed, the only alternative conclusion was "that the density of these stars is extremely small," in which case their masses would be normal and "they may represent (different) stages of evolution of the same bodies." Spectroscopically there is a smooth progression from F through M. Is the sequence of evolution here from G to K one of cooling accompanied with expansion, Pannekoek asked, or heating accompanied by contraction? "While in the natural development of the celestial bodies, as we conceive it, the temperature has a maximum but the density continuously increases, the values obtained here would, according to this interpretation, point to a maximum density in the spectral classes F and G." Pannekoek disagrees with Hertzsprung's suggestion that the early type *c*-stars and the late type stars form one possibly continuous sequence. The K-stars are numerous while the *c*-stars are rare; moreover, there is a continuous progression in the appearance of the metallic lines from early-type non-*c*-stars through the K's, but no conspicuous corresponding features between *c's* and K's, which could be interpreted along evolutionary lines.

Pannekoek also searched spectroscopic double-star data but found only one K-type star, which added little to the information on K-giants. For *c*-stars, however, he found that they combine very great luminosity with very small mass, and consequently their density must be excessively small. This paper by Pannekoek thus emphasized both the importance to evolutionary theory and to stellar constitution, as such, of the observable relation between the spectra and the motions of the stars.

Hertzsprung's second paper, which appeared the following year, stressed even more than his first paper had done the importance of selection of material. He remarked that if the absolute magnitudes of stars of one type, say K, have a greater dispersion than the absolute magnitudes of another class, say A, one will find a different systematic difference between the two types if the stars have been selected on the basis of an apparent magnitude limit or if they have been chosen to a limiting value of the parallax. For stars with observed parallaxes greater than 0".1, he computed the magnitudes the stars would have for a common parallax of 1". Figure 3 is the spectrum-luminosity diagram plotted from his table (Zur Strahlung der Sterne II, *Zeitschrift für*

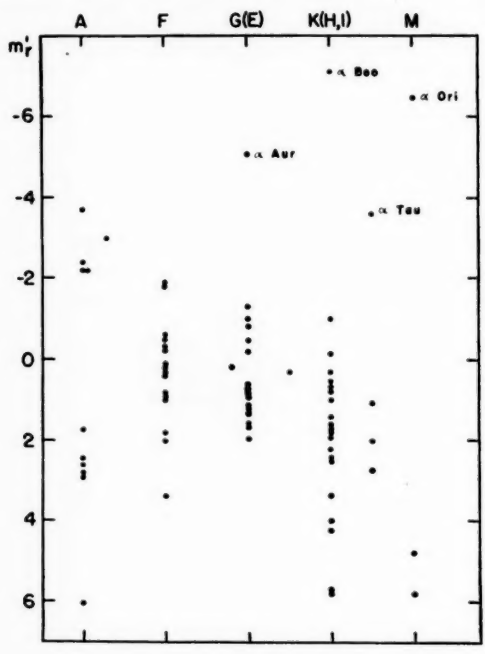


FIGURE 3

Hertzsprung's 1907 data on Spectrum-Luminosity Relation for stars with trigonometric parallaxes greater than 0".1. Magnitudes reduced to $\pi = 1''$.

wissenschaftliche Photographie, V, Heft 3, p. 87, 1907). In this paper he draws the clear distinction between the luminosity function for stars brighter than 5th apparent magnitude and the general luminosity function represented by the volume of space within ten parsecs. In the latter case he found that most stars followed the course acceptable to the current theory of evolution (luminosity decreasing continuously with increasing color or spectral class), while the selection of the apparently bright stars included a preponderance of distant highly-luminous stars which, in fact, are rare per unit volume of space. Among the stars with parallaxes in excess of 0".1 he found that at least four-fifths are absolutely fainter than the sun. Hertzsprung's final discussion of Miss Maury's data, in 1909, while summarizing previous results, dealt primarily with the *c*-stars, whose secular parallaxes and radial velocities he compared with those of the *a* and *b* divisions. Among the later-type stars Miss Maury's classification did not specifically differentiate between the two groups found by Hertzsprung; but from her remarks on the relative intensity of λ 4077 he did find that this line was strong in the stars of small proper motion. Compared with *c*-stars, however, many, like α Boötis, showed appreciable proper motions.

The Russell-Diagram

In his classical lecture of December 30, 1913, on "The Spectra and Other Characteristics of the Stars" delivered before the joint meeting of the Astronomical and Astrophysical Society of America and the American Association for the Advancement of Science, Henry Norris Russell remarked, concerning the two major classes of stars discovered by Hertzsprung, that Hertzsprung "has applied to them the excellent names of *giant* and *dwarf* stars" (Popular Astronomy, **22**, 287, 1914). However, in none of the three papers by Hertzsprung on the luminosities of the stars of Miss Maury's various divisions does he use the terms giant and dwarf, or their German equivalents "Riese und Zwerg." Nor do these terms appear in any of the other of his writings that are listed in the *Jahresbericht* prior to the time of Russell's lecture (*Cf.*, also, Lundmark, "Handbuch der Astrophysik," V, 443, 1932). What Hertzsprung does say (1909) is that the *c*-stars might be considered as the whales among the fishes ("Walen unter den Fischen").

Much of what Russell presented in his 1913 lecture was the synthesis of work of others. Yet so forcefully did he present the material on which he based the arguments for his theory of stellar evolution that he merits the credit for having brought new life to Hertzsprung's outstanding discoveries. It has frequently been remarked (*e.g.*, Lundmark, "Handbuch der Astrophysik," V, 437, 1932) that Hertzsprung's fundamental and pioneering investigations had been undeservedly neglected because they had been published in a comparatively little-known, non-astronomical journal, the *Zeitschrift für wissenschaftliche Photographie*. This criticism is largely justified, but not wholly so in view of the fact that Hertzsprung's third paper on the luminosities of the

stars was published in the *Astronomische Nachrichten* in January, 1909, in which he both repeated and extended his previous conclusions. The first of his three papers on the luminosities of the stars was Hertzsprung's first published paper. The slowness with which it was accepted may be partly a reflection of a common reluctance to heed the work of a new investigator.

In Russell's lecture, he was concerned primarily with his theory of evolution and with the relation of stellar mass to luminosity. He did not go into the matter of spectroscopic differences between stars that have the same spectral class but are of different absolute brightness. By 1913 vastly more material on trigonometric parallaxes, double stars, and open clusters had accumulated than had been available in 1905. The "Russell-Diagrams" consequently looked very much more convincing than they would have from the sparse data on individual stars that had been at Hertzsprung's disposal. The new diagrams might readily have prompted further investigations into spectroscopic parallaxes. Meanwhile, however, such investigations were already being contemplated.

The First Committee on Stellar Classification

In 1910 the first international committee on stellar classification was appointed by the International Solar Union (*Ap. J.*, **33**, 260, 1911). The purpose of the committee was to decide whether or not any particular system of classification should be universally adopted. At that time there was considerable difference of opinion on the advisability of adopting any system based specifically on concepts of stellar evolution. Miss Maury, for example, considered it "of supreme importance that the system to be finally and universally adopted should be *evolutionary*." At the same time she believed the evidence "almost conclusive" that the evolutionary order of the Draper classes, O, B, . . . M, N could not be reversed, and made no reference to the fact that in the preceding months Henry Norris Russell had already indicated that red giant stars may be earlier on the evolutionary scale than yellow giants (*Science*, **32**, 883, 1910), although the accepted opposite concepts would still hold for the dwarf stars. Walter Sidgreaves was opposed to the general adoption of any system yet, because "We are still in want of some indication in the life of a star of declining age, and distinction between heat effect and electrical effect." On the other hand, Edwin B. Frost, who, in 1904 had made a plea for homogeneity in classification and the universal adoption of a system free from theory (*Ap. J.*, **20**, 342, 1904), said that it was desirable that both branches of the (Lockyer's) temperature curve should be recognized; for he felt that "Sir Norman Lockyer must be right, to some considerable extent . . . even if the evidence he has thus far presented may not be entirely convincing." This view had in effect been stated by Russell in his paper on "Some Hints on the Order of Stellar Evolution" (*loc. cit.*) where he stated concerning his own theory, "Its fundamental conception is similar to that underlying Lockyer's classification—from which, however, it differs

radically as regards the criteria for distinguishing rising from falling temperatures."

Those who advocated a purely empirical classification were mainly Russell, Hartmann, Kapteyn, and Schlesinger. These experts were keenly aware of how uncertain any theory of evolution must be. Hence, for any acquired data on stellar spectra to be of permanent value, in spite of changes in theory, such data should be purely observational. For this reason Russell (and he alone) recommended that the peculiar order of the letters designating the sequence of Draper classes be retained—just because that order did not suggest an evolutionary sequence. He stated, "In my opinion, the classification should be based exclusively on a study of the spectra, *i.e.*, of the *line* and *band* absorption, without reference to color, intrinsic brightness, and the like, much less to the theoretical considerations. External considerations should be admitted only (1) in the search for differences, *perceptible in the spectra themselves,* which might otherwise escape notice; (2) in determining which of numerous small differences are entitled to specific rank."

Although the majority of the members of the 1910 Committee commented on the desirability of designating line-widths by symbols as Miss Maury had done, only Hertzsprung and Russell made concrete reference to the importance of determining luminosity criteria for all spectral types. Thus, Russell said, "a comparative study should be made of the spectra of stars of very different total luminosity but the same spectral class (Hertzsprung's 'giant' and 'dwarf' stars)"; while Hertzsprung said, "I imagine for the future a spectral classification in two coordinates, the one giving the normal color index and the other the normal absolute brightness corresponding to the spectrum observed." Karl Schwarzschild predicted that probably more than two variables would be needed completely to describe a spectrum; though he thought it possible that three might suffice. For he felt that the character of the spectrum might depend only on the mass, age, and temperature (or energy-content) of the star.

At the time of the 1911 reports of the Committee, Walter S. Adams of Mount Wilson made no specific mention of giants and dwarfs. But he did point out the need for investigating the abnormal strengths of some lines: "Whether abnormal strength on the part of the enhanced lines indicates high temperature, or some particular condition in the radiating or absorbing gases analogous to that in the electric spark, we do not as yet know. We may hope, however, that this question will be definitively settled by physicists before very long, and in the meantime, if we can accumulate data bearing on the behavior of this class of lines, we shall be in a position, as soon as the physical evidence is available, to make a considerable step forward, perhaps on the side of stellar evolution, but certainly from the point of view of classification." Accordingly the Mount Wilson investigators began work on "measured"

in distinction from "estimated" classes, with the consequent discovery of spectroscopic absolute-magnitude criteria.

Early Discoveries at Mount Wilson

It is not obvious from the *Mount Wilson Contributions* that the discovery of absolute-magnitude criteria by Walter S. Adams and his associates developed purposefully, as one might have anticipated, out of the 1911 conferences and the reports of the Committee on Spectral Classification. Rather, two types of investigations, quite independent of the procedures indicated by Hertzsprung's discovery, led fairly directly to results that appeared at the same time theoretically as well as empirically justifiable. The first of these concerned the comparison of solar disc- and spot-spectra with high dispersion spectra of a few of the brighter stars. The second was an investigation, prompted by Kapteyn, for the purpose of studying space-absorption. Kapteyn suggested that a search be made for differences between the red and the blue parts of spectra of stars of the same spectral class but situated at widely different distances from the sun.

In 1906, Adams (*Mt. W. Contr.*, 12; *Ap. J.*, **24**, 69, 1906) had studied the variations of line-intensities between the solar disc and sun-spots and showed that the spectrum of Arcturus (K-type) closely resembled that of sun-spots. Somewhat later, Hale, Adams, and Gale (*Mt. W. Contr.*, 11; *Ap. J.*, **24**, 185, 1906) showed that temperature differences would easily account for most of the difference between the spots and the disc. The same year, Sebastian Albrecht at Lick Observatory (*L.O.B.*, 106; *Ap. J.*, **24**, 333, 1906) had studied the variations of wave lengths of the sun-spot lines from type to type in order to determine whether or not there is any progressive shift. He found that the changes with increasing type (later than F) were in the same direction as the changes from solar disc to spot. He also noted, qualitatively, the variations in the intensities of the lines. Later, in 1910, Albrecht published a list of some 20 spectral lines whose wave lengths he found to vary with spectral class so consistently that he felt he could predict spectral class to within a very few tenths of a class, simply from measures of variations of wave lengths of critical lines, which should be included in the course of measurements for radial velocity ("On a Quantitative Method for Determining the Spectral Types of the Brighter Stars," *Ap. J.*, **33**, 130, 1910). These various papers did not, however, comment on the variations of any of the line-shifts or intensities with any parameter other than the spectral class or temperature; nor did Albrecht's papers contain any comment on the different origins of the variable from the non-variable lines.

In 1909, Adams discussed further the differences between the disc and spot spectra (*Mt. W. Contr.* 40; *Ap. J.*, **30**, 86, 1909) and at that time practically rejected the possibility that the differences might to any appreciable extent be due to differences in pressure. He reasoned that differences in pressure should be revealed by pressure-shifts. His

spectra, capable of revealing shifts of 0.003 or 0.004 Angstrom, yielded only negative results, indicating that the excess pressure in spots over that of the surface in general could hardly be as much as one atmosphere. Even the single largest observed displacement of 0.008 Angstrom was too low to account for the presence of bands and flutings found in the spectra of the spots.

This complete rejection of pressure to account for the observed differences is somewhat surprising in view of the previous notes by Hale (*P.A.S.P.*, **19**, 239, 1907) and by Hale and Adams (*P.A.S.P.*, **20**, 27, 1908) in which they reported on comparison between spectra of the center, the limb, and spots on the sun. They had found that the majority of the lines that are strengthened in spots are also strengthened at the limb and *vice versa*; and that the lines are shifted toward the red by varying amounts, even differing among the lines of the same element. The lines of the cyanogen flutings in the ultra-violet, however, were not shifted. In general, lines due to elements of high atomic weight were greatly weakened near the limb, whereas those of low atomic weight (including Ca 4227) were considerably strengthened. The strengthened (spark) lines as a rule showed greater average shifts than other lines. While these effects were indicative of change in pressure, Hale recommended that definitive judgment be deferred until the completion of further laboratory experiments on the behavior of spectral lines under increased pressures.

The year following his rejection of pressure effects to account for the differences between spot and disc spectra, Adams, in his analysis of the spectra of Sirius, Procyon, and Arcturus (*Mt. W. Contr.*, **50**; *Ap. J.*, **33**, 64, 1911) had made considerable progress in the interpretation of stellar atmospheres. The nature of pressure shifts had been studied experimentally in the Mount Wilson physical laboratory by H. G. Hale and Adams (*P.A.S.P.*, **23**, 264, 1911). Now in the spectra of the three stars, Adams determined the mean difference in the shifts of the enhanced and the arc lines to an accuracy of 0.1 to 0.2 km/sec, with the following results:

	Weighted Mean Shift Enhanced *minus* Arc Lines	
Star	Km./sec.	Angstroms
Sirius	+0.90	+0.014
Procyon	0.58	0.009
Arcturus	0.08	0.001

In the rich spectrum of Arcturus he likewise analysed the displacements, element by element, relative to their mean, and noted again the resemblance between Arcturus and sun-spot spectra, "a large portion of the lines of titanium, vanadium, and calcium being greatly strengthened, the enhanced lines weakened, and those of iron and chromium either strengthened or weakened according to their behavior under different conditions of temperature." Adams considered the most striking feature of the comparisons he had made to be "the remarkable resemblance they

bear to the displacements found in the investigation of the lines at the sun's limb" where the enhanced lines were shifted toward the red relative to the arc lines (Ti, V, Ca shifted less than Fe, while H showed no appreciable displacement). He found similar shifts between Sirius and Procyon, and possibly to a slight degree in Arcturus. Hence he considered it probable that the cause giving rise to the systematic differences in the stellar spectra is the same as that which produces the displacements observed at the sun's limb. The possibility that such displacements might be pressure effects had already been considered in 1907 by Halm (*A. N.*, **173**, 273, 1907) and was further analysed by Adams himself in 1909 (*Mt. W. Contr.* 43; *Ap. J.*, **31**, 30, 1910). The solar effects thus having been ascribed mainly to pressure, "we may consider pressure as the principal agent in causing the displacements in the stellar spectra." The various shifts he observed indicated a pressure of 12 atmospheres in the atmosphere of Sirius and 7 in Procyon. He further commented (*Ap. J.*, **33**, 70, 1911), "The hypothesis has sometimes been suggested, based on considerations of average density and intrinsic luminosity, that no true photosphere of the solar type exists in the case of Sirius, but rather, that the star consists of a vast mass of gas increasing in density toward the center but with no actual surface of condensation. In such a star it is evident that the light could come from regions extending to great depth in which the pressures are high." In Procyon the spectrum indicated atmospheric conditions intermediate between those found in Sirius and the sun. For Arcturus he deduced that the star has "a definite photosphere, and that the light emitted by it would come from comparatively shallow depths, and so from regions of relatively low pressure." Furthermore, he deduced that "the general arrangement" of the various gases in the atmospheres of Arcturus and the sun are about the same, hydrogen rising to great heights, magnesium, neutral calcium, and titanium to intermediate levels, while iron is a low-level element. This investigation, relating to pressure-shifts rather than line-intensities, and therefore requiring accurate measurements, was nevertheless a direct forerunner to the discovery of the more readily examined absolute-magnitude criteria.

The second type of investigation by Adams that had bearing on his subsequent spectroscopic parallax developments had been proposed by Kapteyn for the purpose of studying the absorption of light in space. It had been suggested that the relative intensity of the violet part of the spectrum, as compared with the red, should be stronger in nearby than in very distant stars. Consequently Adams (*Mt. W. Contr.* 78; *Ap. J.*, **39**, 89, 1913) selected pairs of stars in which both members had almost exactly the same spectral class, but for one star the proper motion was large and for the other negligibly small, the motions being indicative of differential distance. It was extremely important to match the spectral classes, especially in the later types; for it was well known that the intensity in the violet falls off rapidly with only a comparatively

small increment in type. It was also important that the two stars of a pair be photographed at very nearly the same zenith distance. Within these restrictions, Adams found 40 pairs ranging from B8 to K6. While no significant differences were found in the four pairs having spectral classes B8 to F4, all of the others showed marked differences, and in all of them the spectrum was weaker and shorter in the violet of the star of small proper motion. These conclusions were shortly verified statistically (*P.A.S.P.*, **26**, 90, 1914) from more abundant but less critically selected data, secured from the available radial-velocity plates at Mount Wilson for about 100 large and 60 very small proper-motion stars. They confirmed the conclusion that the spectra of the small proper-motion stars are the weaker in the violet, and that the difference increases progressively with advancing a spectral type. But Adams was not satisfied that the conspicuous differences found could be wholly accountable to interstellar absorption; for "the results so far found may be explained equally well as an effect of absolute brightness." (At this time, *loc. cit.*, *P.A.S.P.*, he attributed the origin of the concise term "absolute magnitude" to Kapteyn.) Moreover, since the two stars of each pair compared in the first paper were of nearly the same apparent magnitude, the more distant stars were intrinsically much brighter and also probably more massive. Hence, he concluded, "If the atmosphere of the more massive star absorbs more strongly than that of the smaller, which seems fairly probable from physical considerations, this would account for the differences observed." In order to separate absolute-magnitude from space-absorption effects, Kapteyn then prepared a list of stars of widely different luminosity at approximately the same distance from the sun. But the few plates available to Adams at the time did not yet reveal anything conclusive.

The Work of Adams and Kohlschütter

When Arnold Kohlschütter came to Mount Wilson in 1914 as visiting astronomer it was already known from Adams' previous work (as we have described) that there were three major differences between the spectra of large and of small proper-motion stars of approximately the same apparent magnitude: (1) For spectra of the same density in the red, the violet was very much weaker in the small proper-motion stars. (2) The hydrogen lines were abnormally strong in the small proper-motion stars. (3) Certain other lines were stronger in one group than in the other. Adams and Kohlschütter then collaborated in the investigation of the possibility of applying these facts specifically to the determination of absolute magnitudes. On the first point, the paper by Adams and Kohlschütter (*Mt. W. Contr.* 89; *Ap. J.*, **40**, 385, 1914) added but little on the application of the extent of the spectrum to the determination of luminosities. As regards the hydrogen intensities, it was assumed, simply as a working hypothesis, that interstellar hydrogen might have contributed to the increase in the intensities of the stellar lines. To test this theory, the radial velocities of the stars were deter-

mined separately from the hydrogen and other lines. The test showed that interstellar hydrogen absorption could account for no more than two per cent of the observed absorption, which must therefore constitute an intrinsic absolute-magnitude effect. However, in this early work this criterion was not actually calibrated for absolute magnitude, and it remained for Miss Anger at Harvard in 1930 to apply measurements of hydrogen line intensities to the practical determination of the absolute magnitudes of early type stars (*H. C.*, 352, 1930; 362, 1931; and Anger and Payne, *H. C.*, 363, 1931).

Examination of lines that had figured in spectral classification as well as the lines previously noted to have been affected by absolute magnitude were carefully studied by Adams and Kohlschütter for the dual purpose of arriving at a scheme for the *measurement* of spectral class, as distinguished from *estimates* based on the over-all appearance of a spectrum. For the prospective spectral classification, the relative intensities in pairs of lines were estimated (in a system analogous to Argelander's method of estimating brightness of variable stars). The one member of a pair was a line known to increase in intensity with advancing spectral class while the second member decreased. Similarly, other pairs were chosen in which one member varied with absolute magnitude and the other presumably did not to any appreciable extent. Of the 23 pairs in which differences were estimated, those that showed the most conspicuous dependence on spectral class all happened to involve the hydrogen lines, namely, for classes F8 to G6, the ratio of Hγ successively to 4227, 4326, 4352, 4405, and 4384; and for classes G6 to K9, the ratio of H to 4326, 4352, and 4405, and the ratio of Hβ to 4872 and 4958. The lines most sensitive to luminosity were found to be 4216 Sr+, 4395 Ti+, V, Zr, and 4408 V, Fe, which are strong in high-luminosity stars; and 4325 Sc, 4335 Ca, 4456 Ca, and 4535 Ti which are weak at high luminosity. Other lines showed some absolute magnitude effects, but the following pairs gave the largest average differences between bright and faint stars and were adopted for further work on individual stars:

$$\frac{\text{4216 Sr+}}{\text{4250 Fe}}, \quad \frac{\text{4395 Ti+}}{\text{4215 Sc+, Fe}}, \quad \frac{\text{4456 Ca}}{\text{4462 Fe}}, \quad \frac{\text{4456 Ca}}{\text{4495 Fe}}.$$

These pairs showed differences between the ratios for high and low luminosity stars greater than four steps on a scale of 1 to 12. Other promising pairs for which the differences between the averages for high and low luminosity exceeded three steps were 4337/Hγ, 4415/4456, 4495/4497, and 4325/4326 while others indicating possible small absolute magnitude effects were 4415/4435, 4435/4444, 4250/4255, 4271/4275, 4462/4495, and 4415/4535. The five most promising ratios were estimated on the spectra of 162 stars of types F8-K9, over half of which were main sequence stars. Proper motions were available for all these stars and trigonometric parallaxes for 95. The authors computed paral-

laxes from the proper motions, μ, by a formula derived by Kapteyn and Kohlschütter,

$$\log \pi = -1.00 - 0.005\text{m} + 0.86 \log \mu.$$

Adams and Kohlschütter then computed absolute magnitudes (defined as the apparent magnitudes corresponding to a fixed parallax of 0".1) from both the trigonometric and proper-motion parallaxes. These showed nearly linear relations with the spectral line-intensity ratios. The mean relations they found were

$$M = 5.6 - 1.6D \text{ for F8-G6}$$
$$M = 6.8 - 1.8D \text{ for G6-K9}$$

where the values D are the mean ratios for the five most promising pairs listed above. The difference between the constants 5.6 and 6.8 is the difference between the average absolute magnitudes for the two spectral groups. If we plot the astrometrically determined absolute magnitudes against the spectroscopic values given in this first list, we find that all of the points fall into two well-separated areas, one corresponding to giant, the other to dwarf stars; but within each area very little correlation between the spectroscopic and astrometric results is found. Nor does the Russell-Diagram for these early results inspire particular confidence in the light of future results. In a series of papers in the Proceedings of the National Academy of Sciences (Vol. 2, 1916; *Mt. W. Comm.* Nos. 23-26, 1916), however, Adams extended his investigations and refined his determinations of spectroscopic parallaxes. The mean deviation, without regard to sign, of his spectroscopic from trigonometric parallaxes for over a hundred stars (mostly dwarfs) was ±0".024. The Russell-Diagram plotted from these 1916 results (not published at the time) shows a greater absolute-magnitude dispersion than later results, but the now standardly recognized features are well marked.

Subsequent Mount Wilson Results

The papers just described were considered purely exploratory; when the list of 500 spectroscopic absolute magnitudes and parallaxes in *Mount Wilson Contribution* 142 by Adams and Joy appeared in 1917 it was labelled "First List." The results plotted in a Russell-Diagram (Figure 4, not published as such by the authors) differs little from similar modern diagrams obtained from trigonometric parallax data. Indeed, the calibration of these stars depended primarily on the available trigonometric parallaxes for 309 of the 500 stars. In the final spectroscopic results the systematic difference between the spectroscopic and the trigonometric parallaxes was found to be negligible while the average difference irrespective of sign was ±0".026.

Meanwhile Adams was also enjoying the collaboration of Gustav Strömberg who was primarily interested in the statistical problems of the determination of mean absolute magnitudes and luminosity functions from radial velocity and proper motion data. His investigations aided significantly in the calibration of the spectroscopic material,

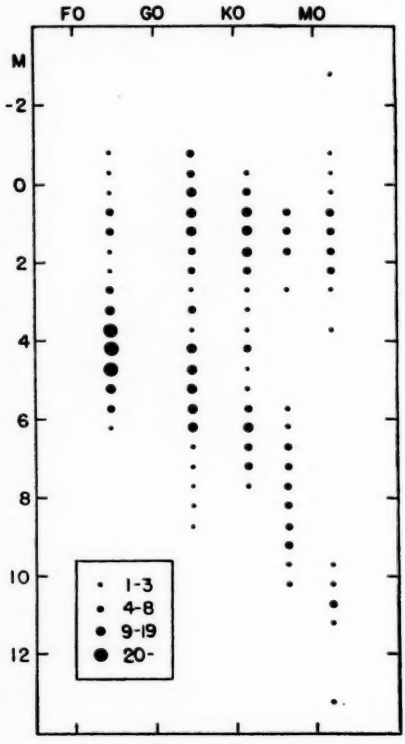


FIGURE 4

Magnitudes and spectra from *Mt. W. Contr.* 142, 1917. Size of symbols according to number of stars.

especially for the giant stars whose measured parallaxes are nearly all smaller than their probable errors. In principle the methods more fully developed by Strömberg (to be described elsewhere) had already been used by Hertzsprung and Kapteyn. Their application to the specific problems of the calibration of the spectroscopic absolute magnitudes greatly increased the weight of the spectroscopic results.

Subsequent Mount Wilson Catalogues of spectroscopic parallaxes included increasing numbers of stars, although each succeeding list included revisions of earlier values. Three general catalogues and several lists covering limited spectral classes (Table IV) have been issued. The last two items noted in Table IV (for A and B-type stars) are not altogether homogeneous with the others, in that the absolute magnitudes were based on spectral characteristics other than relative line-intensities. Here the criterion adopted was the sharpness of the lines. The

TABLE IV

MOUNT WILSON SPECTROSCOPIC PARALLAX DETERMINATIONS

Reference			Number of Parallaxes	Spectral Classes	Type of Calibration	Authors
Date	*Mt. W. Contr.*	*Ap. J.*				
1917	142	**46**, 313	500	F0-M	Trig.	Adams, Joy
1921	199	**53**, 13	1646	A5-M	Trig., parallactic, and peculiar motions	Adams, Joy, Stromberg, Miss Burwell
1926	319	**64**, 225	410	M	Pec. motions for giants, trig. for dwarfs	Adams, Joy, Humason
1935	511	**81**, 187	4179	A5-M	Trig. and motions	Adams, Joy, Humason, Miss Brayton
1922	244	**56**, 242	544	A	Group Motions	Adams, Joy
1923	262	**57**, 294	300	B	Group Motions	Adams, Joy

authors commented, "With some notable exceptions, such as α Cygni and stars of similar spectra and those in which certain lines like λλ 4077, 4216, and 4481 are especially strong, the stars of this type do not show the large variations in the intensities of the lines which appear in the later types. They do, however, show very great differences in the appearance of the lines, in some stars such as Sirius the lines being sharp and well defined, and in others such as Altair very diffuse and vague." Stars in the Taurus and Ursa Major groups and other stars whose absolute magnitudes were known to a high degree of accuracy were classified both according to the ordinary spectral sequence and according to the sharpness of the lines which were classified *n* or *s* (*c*-stars excluded). It was found that the absolute magnitudes progressed smoothly with spectral class, but that the hazy-line (*n*) stars were uniformly fainter than the sharp-line stars.

Figure 5 shows the mean calibration curves for stars classified B0

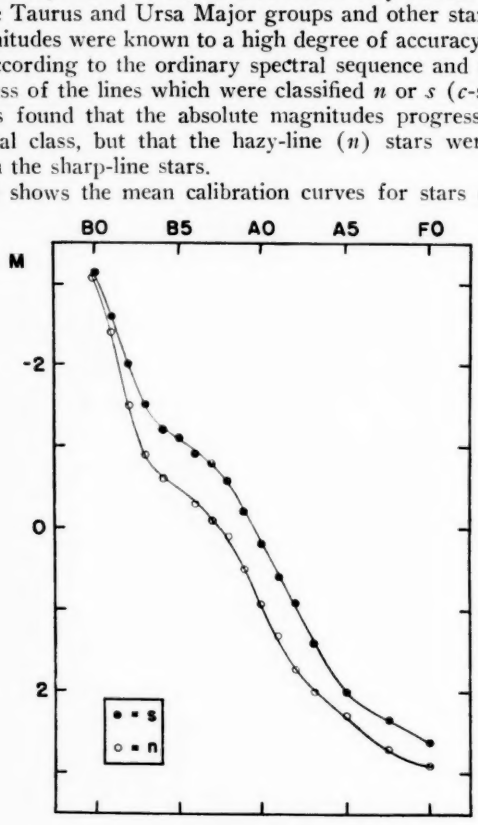


FIGURE 5
After Adams and Joy, *Mt. W. Contributions* 244, 262, 1923.

and F0 by Adams and Joy. This early investigation was not adequate for analyzing the total dispersion of the absolute magnitudes within any spectral sub-division; the *n* and *s* designations served as two discrete "luminosity classes" between which no graduations were recorded at that time. Convincing as the "calibrations" in Figure 5 look, the new

method for ascertaining absolute magnitudes from simple visual inspection of line quality was not accorded general acclaim. There was some question as to the extent to which the apparent haziness of the lines might depend upon plate quality (instrumental effects and observational conditions), especially in case the criterion was to be applied to objective prism work. But this was a comparatively minor point, indicating the need for carefully controlled exposures. The more fundamental query that arose was whether the observed correlation between intrinsic line-quality and absolute magnitude was really proof of an absolute-magnitude criterion or rather a possible reflection of systematic relative errors in spectral classification. It was soon noticed that the average discrepancy between the Mount Wilson and the Harvard spectral sub-classes of the early-type stars was systematically different for sharp and hazy line spectra. Already in 1923 Lindblad (*Ap. J.*, **59**, 305, 1923) and independently Miss Fairfield in 1924 (*H.C.* 264) showed that the absolute magnitude difference between the *n*- and *s*-line stars vanished if the Mount Wilson spectral classes were replaced by Harvard classes. The cause for the difference in classification may be attributed to the accidental circumstance that the Mount Wilson spectra for the most part do not extend as far into the violet as do the Harvard spectra. Consequently, less attention can be given at Mount Wilson to the H- and K-lines which play a prominent role in the Harvard classification of early-type spectra.

Miss Fairfield, although she found no significant difference between the spectroscopic magnitudes of the two groups (*c*-stars excepted), did find that "a definite correlation of line-character with reduced proper motion appears when the averages of large numbers of stars are considered." The reduced proper motions (H-values) implied an average absolute magnitude difference of $+0^{M}.6$ between the *n* and *s* spectra of the same *Harvard* class. However, she thought it possible that "This condition may indicate dependence of line-character on linear speed rather than on intrinsic brightness," the stars with the smaller peculiar velocities having the sharpest lines. This was an interesting suggestion: but she did not comment that it could not account for the fact that Adams and Joy had observed both *n* and *s*-line spectra within the same cluster, all of whose stars have the same speeds (Taurus 23 n, 11 s, 1 ?; Perseus 7 n, 3 s; Praesepe 4 n, 2 s; and Ursa Major 13 n, 8 s, 1 ?).

(To be continued)

The Planets in January, 1951

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. During this month the sun will move northward from 23 to 17 degrees south declination. Although the earth is at perihelion, that is, closest to the sun, on January 1, this month is usually the coldest of the winter.

Moon. The phases of the moon will occur as follows:

New Moon	January	7	2 P.M.
First Quarter		14	6 P.M.
Full Moon		22	11 P.M.
Last Quarter		30	9 A.M.

The moon will be at perigee, that is, nearest to the earth on January 6. Again there will be an occultation of the Pleiades, visible from the northeast quarter of the United States, beginning shortly after 3 P.M. on January 17.

Evening and Morning Stars. In the southwest twilight will appear Mars, and later in the month, Venus. Jupiter will be high in the southwest in the early evening, while Saturn will be rising after 11 P.M.

Mercury. This elusive planet will stand more than 24 degrees west of the sun on January 23, so that it may be visible low in the southeast dawn, within a week of that date.

Venus. This brightest planet is slowly moving clear of the sun in the evening sky. By the end of the month it will be visible, low in the southwest twilight, until 6 P.M.

Mars. Mars may still be seen, as a star fainter than Fomalhaut, low in the southwest twilight until after 6 P.M. It will be about a degree north of the moon on January 9.

Jupiter. Until its setting at about 7 P.M., Jupiter will appear as the most brilliant star in the southwest evening sky.

Saturn. Saturn will be rising before 11 P.M. at the last of the month, and thus will be most favorably situated for observation just before dawn.

Uranus. Uranus will be moving slowly westward at about midway between ϵ and μ Geminorum.

Neptune. Neptune will be almost stationary at about 5 degrees north of Spica.

Department of Mathematics, Temple University, Philadelphia, Pa.,
November 8, 1950.

Asteroid Notes

By HUGH S. RICE

The next rather bright asteroids becoming visible in small instruments after the ones mentioned in the last issue, are the following: 49 PALES, of magnitude 10.1, is in the northeast corner of Taurus, crossing the galactic equator. Opposition occurs on December 19. 37 FIDES, of magnitude 9.3, is in southernmost Auriga, north of Pales. Opposition occurs on December 22. 6 HEBE, of magnitude 8.1, is found mostly in eastern Orion, with opposition on December 26. It appears to have a rapid northward motion, and on January 25 is in conjunction with Alpha Orionis, and less than 2° north of that famous star. Thus it should be located easily in a small glass. 385 ILMATAR is in Auriga, with magnitude 10.2 and opposition date December 26. The declination shows it quite far north. A few asteroids per year assume even greater declinations. For instance, 1318

NERINA goes to declination 64° north on December 25; and this appears to be the planet farthest north of any in 1950.

The following are the ephemerides, with the last position in each case done by extrapolation by us, the rest of the places being taken from the data supplied by the minor-planet headquarters at the Cincinnati Observatory.

ASTEROID EPHEMERIDES

49 PALES

1950-51	α h m	δ ° ′
Dec. 5	5 58.9	+25 36
15	5 49.6	+25 23
25	5 40.1	+25 6
Jan. 4	5 31.5	+24 47
14	5 25.1	+24 29
24	5 22.1	+24 13

37 FIDES

1950-51	α h m	δ ° ′
Dec. 5	6 13.7	+28 44
15	6 4.2	+28 56
25	5 53.6	+28 59
Jan. 4	5 43.7	+28 53
14	5 36.1	+28 38
24	5 32.3	+28 14

6 HEBE

1950-51	α h m	δ ° ′
Dec. 5	6 37.1	+ 3 10
15	6 28.3	+ 3 39
25	6 17.9	+ 4 36
Jan. 4	6 7.6	+ 5 55
14	5 58.8	+ 7 26
24	5 52.9	+ 9 8
Feb. 3	5 51.2	+10 56

385 ILMATAR

1950-51	α h m	δ ° ′
Dec. 5	6 43.5	+42 45
15	6 34.0	+43 14
25	6 22.1	+43 21
Jan. 4	6 9.7	+43 5
14	5 58.6	+42 27
24	5 51.0	+41 27
Feb. 3	5 48.9	+40 5

Hayden Planetarium, American Museum of Natural History,
New York, 1950 November 21.

Occultation Predictions for January, 1951

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1951	Star	Mag.	IMMERSION Green-wich C.T. h m	a m	b m	Angle E from N °	EMERSION Green-wich C.T. h m	a m	b m	Angle E from N °
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Jan. 10	42 Aqar	5.6	22 18.2	+0.5	+2.4	357	22 55.1	−2.0	−2.6	291
16	ε Arie	4.6	23 47.3	−0.5	+4.0	11	0 44.8	−2.8	−1.9	290
17	17 Taur	3.8	20 33.2	−0.5	+1.8	69	21 43.8	−0.8	+2.1	239
17	20 Taur	4.0	21 19.8	−0.2	+2.6	36	22 27.2	−1.7	+1.1	270
17	22 Taur	6.5	21 57.2	..	..	353	22 24.5	..	..	313
18	BD+26°731	6.5	21 56.1	+0.1	+3.0	29	22 53.0	−2.0	+0.3	291
20	406 B.Taur	5.6	8 36.7	−0.1	−1.3	88	9 32.7	+0.5	−1.4	288

Date 1951	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′									
21	49 Auri	5.0	2 33.8	−2.1	+2.5	56	3 42.7	−1.8	−2.7	317
26	*c* Leon	5.1	10 10.0	−0.9	−1.9	130	11 18.6	−0.6	−1.9	303
27	9 B.Virg	6.2	11 4.0	−1.3	−1.5	103	12 7.9	−0.5	−2.2	328
30	43 H.Virg	5.6	8 48.7	−1.9	+0.7	92	9 51.5	−0.7	−1.2	337
30	231 G.Virg	6.4	9 58.9	−1.6	−0.3	114	11 15.7	−1.5	−1.1	312
30	236 G.Virg	5.7	10 59.2	−2.1	−0.3	92	12 8.0	−1.3	−1.7	329
	OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′									
Jan. 14	60 Pisc	6.2	3 48.1	−0.9	−3.5	117	4 25.0	−0.4	+2.6	186
16	47 Arie	5.8	21 42.3	−1.3	+1.3	94	22 42.2	−0.2	+2.9	202
17	η Taur	3.0	21 44.9	−1.3	+0.7	113	22 29.7	+0.5	+3.4	194
20	406 B.Taur	5.6	8 38.9	−0.1	−2.1	119	9 38.7	−0.2	−1.0	260
21	49 Auri	5.0	1 57.8	−1.1	+2.7	54	3 8.4	−2.3	−1.2	305
26	*c* Leon	5.1	10 1.5	−0.4	−2.6	167	11 1.8	−1.8	−1.2	273
27	9 B.Virg	6.2	10 42.8	−1.3	−1.7	135	11 58.3	−1.2	−1.8	304
30	43 H.Virg	5.6	8 26.3	−0.6	0.0	131	9 34.4	−1.2	+0.1	298
30	231 G.Virg	6.4	9 39.2	−0.5	−0.8	152	10 45.8	−2.0	+0.2	279
30	236 G.Virg	5.7	10 27.5	−1.3	−0.4	127	11 44.7	−1.7	−0.7	302
	OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +31° 0′									
Jan. 20	406 B.Taur	5.6	9 6.3	..	..	165	9 35.3	..	..	218
21	49 Auri	5.0	1 31.6	−1.1	+1.6	76	2 54.5	−2.2	+0.5	276
27	9 B.Virg	6.2	10 54.8	−0.6	−2.7	166	12 1.0	−2.1	−1.2	278
29	*i* Virg	5.6	10 31.5	−2.6	+0.1	96	11 38.7	−0.7	−2.3	345
30	43 H.Virg	5.6	8 33.5	+0.5	−2.2	175	9 17.3	−2.3	+1.8	256
30	236 G.Virg	5.7	10 29.6	−0.3	−1.7	164	11 32.8	−2.7	+0.3	270
	OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′									
Jan. 14	60 Pisc	6.2	3 4.4	−2.7	−1.5	98	4 1.3	−0.5	+2.9	187
14	62 Pisc	6.1	4 19.3	−0.8	+1.9	21	5 19.3	−1.1	−1.6	273
21	49 Auri	5.0	1 43.8	..	..	15	2 8.1	..	..	334
29	*i* Virg	5.6	9 56.1	−0.9	−0.2	128	11 8.1	−1.2	−0.6	310

METEORS AND METEORITES

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

The Report of the Retiring President of the Meteoritical Society for the 1946-50 Term*

ARTHUR S. KING
925 Topeka Street, Pasadena 6, California

In presenting this summary, as required of the retiring President by the By-laws of the Meteoritical Society, I have attempted what may be called a "sampling" process in mentioning briefly some of the high-lights in the meteoritical re-

*Read at the end of the 13th Meeting of the Society, inside the rim of the Barringer Meteorite Crater of Arizona, on the afternoon of 1950 September 7.

search of the past 4 years, well knowing that some important topics will not receive the notice they deserve.

The period covered by this report (1946-50) began when our country was commencing to put things to rights after a great war, in which many members of the Meteoritical Society had used their special abilities in the service of the government. Some of these members are still thus engaged.

Meetings of the Society have been held annually in these years, beginning with the first post-war meeting at Flagstaff, Arizona, in 1946. In 1947, the Society met with the Pacific Division of the American Association for the Advancement of Science in San Diego, California, and subsequent meetings were held at the Institute of Meteoritics of the University of New Mexico in Albuquerque in 1948, and at the University of Southern California in Los Angeles, California, in 1949. In each case, 2 days of regular sessions were followed by excursions to points of scientific interest in the neighborhood. Evening lectures by scientists in other fields added to the interest of these meetings.

The scope of the Society's work has been extended by the formation of a Meteor Section. It was felt that the interest of many of our members in meteoric phenomena justified the active participation of the Society in this work, with such machinery as it has at its command, under the direction of a specialist and in full coöperation with the American Meteor Society, which has carried on this work for many years under the able leadership of C. P. Olivier. As the first Director of the Meteor Section, C. C. Wylie, Professor of Astronomy in the State University of Iowa, was named by the Council of the Meteoritical Society for the term ending in 1950. The office of the Director, who is a member of the Council, will henceforth be filled by election every 4 years. A systematic program for the observation and recording of meteoric phenomena has been laid out by Director Wylie under the headings of: (*a*) photographic work on shooting-stars; (*b*) visual work on shooting-stars; (*c*) radar observations on shooting-stars; and (*d*) shadow-casting and detonating meteors. This expansion of the work of the Society will doubtless fill a need for those members especially interested in the behavior of objects in our atmosphere that may or may not reach the Earth. This statement may sound as tho the study of "flying saucers" might be included, but I will leave that point to the judgment of the Director of the Meteor Section! In the field of meteor research, I can give only mention to the work of P. M. Millman and D. W. R. McKinley of the Dominion Observatory, Ottawa, Ontario, Canada, in mapping meteor paths by means of radar echoes; to the observations along several lines by F. L. Whipple of the Harvard College Observatory; and to the spectrum observations of Perseid meteors by J. A. Russell of the University of Southern California. Each research deserves an extended review.

Another project undertaken by the Society is the preparation of a textbook on meteoritics, the chapters to be written by various specialists, under the editorship of F. C. Leonard. As to the need for such a book, it is enough to say that the last book of this sort, but of smaller scope, was written by O. C. Farrington over 35 years ago. As the plans for this publication are being discussed by the committee now in Flagstaff, progress reports must be left to the next administration.

As was to be expected, improved data made desirable a revision of the classification of meteorites according to their composition and differences from others of the same general type. A simplification of the classification of G. T. Prior (1920) and a revision of the symbolism have been worked out by F. C. Leonard (1948). In this classification, 3 divisions, aerolites, siderolites, and siderites, are

divided into 7 classes, and these in turn into about 30 subclasses, on the basis of a gradual change in the proportions of certain chemical elements with respect to others. Leonard has published also a catalog of the 66 largest individual meteorites known,† with the more important data concerning them; and he has further developed and systemized the use of the coördinate number (CN), which designates the geographical location of a fall.

The outstanding meteoritical phenomenon of recent years in the United States was the appearance, on 1948 February 18, of a very large and brilliant fireball over the midwestern states. Fragments of the meteorite were found in an extensive area in Norton County, Kansas, and the largest specimen, a magnificent stony meteorite weighing over a ton, across the state line in Furnas County, Nebraska. The searchers received excellent coöperation from those living in the area, both civilians and military personnel. This aerolite is described by Leonard as "a fragile, friable, ferriferous, calcium-poor (enstatite) achondrite, with nickel-iron inclusions, of class A_2." The work of locating the strewn-field, the finding of the larger fragments, and the transportation of the great achondrite, which is by far the largest known stony meteorite, have all been well described by Lincoln LaPaz.

A preliminary report on the mineralogy of the Norton-Furnas meteorite, by C. W. Beck and LaPaz, calls attention to many points of resemblance to the "whitleyite" that fell at Cumberland Falls, Kentucky, on 1919 April 9. The study shows, however, that the Norton-Furnas stone "possesses certain features so distinctive that it seems quite possible that it will serve as the type stone of a new class of achondrites," which has already been named "nortonite" (subclass, A_2no). Beck and LaPaz found that to an even greater extent than the celebrated whitleyite, which G. P. Merrill regarded as supplying "direct evidence of the destruction of some preëxisting planet," the Norton-Furnas meteorite shows, in several of its mineralogical peculiarities, "convincing evidence of having undergone such metamorphic action as accompanies the crustal movements incidental to mountain-making on a planetary scale."

A meteoritic fall of great interest occurred on 1947 February 12, in eastern Siberia. The reports by Russian scientists are not as complete as one could wish, but evidently the fall consisted of a shower of iron meteorites. These produced 120 craters with diameters ranging from 60 cm. to 28 meters. It is estimated that the total meteoritic mass that reached the Earth may have amounted to 100 tons, of which only about 5 tons were collected. Specimens weighing up to 300 kg. resemble externally the Canyon Diablo, Arizona, and Henbury, Central Australia, meteorites; their internal structure shows peculiarities that promise interesting results when this fall is more fully reported.

The Wolf Creek Crater in Western Australia, first observed in 1947 by oil prospectors from an airplane, was later explored on the ground, and its meteoritic origin confirmed. Papers by Frank Reeves and E. P. Henderson, presented at this meeting, describe the Crater and the iron-oxide material found in it. This Crater has the distinction of being the second-largest meteorite crater known, its diameter of 2,800 feet at the bottom and its depth of 150 feet being exceeded only by the corresponding dimensions of the Barringer Meteorite Crater of Arizona.

On the subject of meteorite craters, I will mention the very interesting airplane observation by W. W. Zimmerman (1948) that the Barringer Crater is not

†The 1-ton Furnas County, Nebraska, aerolite, since recovered (*post*), would constitute the 67th meteorite weighing upward of 400 kg.

circular, but has the form of an approximate square with rounded corners. This fact should interest the geologists, and we may expect explanations to be offered.

In recent years, meteorites have taken an important place in the study of the cosmic abundance of the chemical elements, and in the past 3 years a very valuable contribution on the quantitative side has been made thru the investigations of Harrison Brown, of the Institute for Nuclear Studies of the University of Chicago. The distribution of elements in celestial bodies has been a major topic in astrophysics for many years, an outstanding research being that of H. N. Russell, in 1929, on the abundance of elements in the Sun. On the meteoritical side, extensive tables of relative abundances, based on the analyses of large numbers of iron and stony meteorites, were published by Walter and Ida Noddack (1930) and by V. M. Goldschmidt (1935). The available data have been coördinated by Brown, with additional experimental material of his own, in a series of papers. Brown discusses the century-old hypothesis that meteorites are fragments of a disrupted planet that moved between the orbits of Mars and Jupiter, and considers that "the investigations to date have resulted in the following conceptual advances: (1) belief that the dense core of the Earth, as defined by seismic data, is probably similar to nickel-iron meteorites in composition; (2) belief that the silicate phase of stony meteorites is similar to the mantle surrounding the core of the Earth; (3) realization that chemical equilibrium, or at least something approaching equilibrium, at one time existed between the various meteoritic phases."

The studies of Brown and Claire Patterson lay stress on the fact that the phase, metallic or stony, in which a given element tends to concentrate, depends clearly upon the affinity of the element for oxygen. They examined equilibrium conditions, which point to a probable temperature of 3000°C. and a pressure of 10,000 to 100,000 atmospheres. The chemical relationships between igneous rock, plateau basalt, and stony meteorites were studied. After a very painstaking analysis, the simplest conclusion, according to Brown and Patterson, is that meteorites are fragments of a planet similar to the Earth in general physicochemical characteristics, with the iron meteorites coming from the core of the planet and the stony meteorites from the envelope. The data on which this conclusion is based consist of a long series of tables and graphs, and there is no question that a strong case on the quantitative side has been built up for the hypothesis connecting iron and stony meteorites with the core and mantle of a disrupted planet.

Obviously it has been impossible, in this very sketchy report, to go into details on any subject. I trust, however, that the foregoing remarks will show that meteoritics is a growing science, and that meteoriticists, in addition to discovering and analyzing new specimens, are taking advantage of opportunities to enter new fields, finding that the rich collection of data now available may throw light on some of the vital questions in other sciences.

Report on the 13th Meeting of the Society

JOHN A. RUSSELL, *Secretary*

Department of Astronomy, University of Southern California, Los Angeles, California

The opening session of the 13th Meeting of the Meteoritical Society was held at the Museum of Northern Arizona, Flagstaff, Arizona, on Tuesday morning, 1950 September 5.

The following 14 members and a number of guests were in attendance at one or more of the sessions: C. A. Bauer (Ann Arbor, Michigan), L. F. Brady (Flagstaff, Arizona), J. D. Buddhue (Pasadena, California), T. E. Johnson (Winslow, Arizona), Mrs. T. E. Johnson (Winslow, Arizona), A. S. King (Pasadena, California), C. O. Lampland (Flagstaff, Arizona), L. LaPaz (Albuquerque, New Mexico), F. C. Leonard (Los Angeles, California), O. E. Monnig (Fort Worth, Texas), J. S. Rinehart (China Lake, California), S. P. Roach (Ogden, Utah), J. A. Russell (Los Angeles, California), and W. J. C. Weiss (San Antonio, Texas).

President King, who presided at all the sessions thruout the meeting, introduced Dr. Harold S. Colton, the Director of the Museum of Northern Arizona, who extended a cordial word of welcome to the Society on behalf of the Museum. Morning and afternoon sessions for the presentation and discussion of papers were held at the Museum on September 5th and 6th. Twenty-six (26) papers were presented, 10 of which (marked *) were read by proxy in the absence of their authors, and one of which (marked †*) was presented by title only.

List of Papers Read at the 13th Meeting

(in the order of presentation)

Morning Session, September 5

1. "Some Observations on High-Speed Impact," John S. Rinehart, U. S. Naval Ordnance Test Station, China Lake, California.

*2. "Daytime Meteors of August 7, 1869," Dorrit Hoffleit, Harvard College Observatory, Cambridge, Massachusetts (read by Dr. Leonard).

*3. "The Lost Port Orford, Oregon, Meteorite," J. Hugh Pruett, University of Oregon, Eugene (read by Dr. Leonard).

†*4. "A Living Universe," Asbjorn P. Ousdal, P.O. Box 807, Santa Barbara, California.

5. "A Proposed Curriculum in Meteoritics for College Students," Frederick C. Leonard, University of California, Los Angeles.

6. "A Recently Discovered Possible Meteorite Crater in Quebec, Canada," and "Why Study Meteorites?," Frederick C. Leonard.

Afternoon Session, September 5

7. "A Meteorite, Presumably Canyon Diablo, Arizona, Found on the Floor Level of a 14th-Century Ruin," L. F. Brady, Museum of Northern Arizona, Flagstaff, Arizona.

*8. "The Wolf Creek Crater of Australia," Frank Reeves, Washington, D. C., & Edward P. Henderson, U. S. National Museum, Washington, D. C. (read by Mr. Brady).

*9. "Altered Meteoritic Iron Oxides," Edward P. Henderson (read by Mr. Brady).

*10. "The Probably Meteoritic Origin of Certain Specimens of Nickel Coins Struck in Bactria before 200 B.C.," Mohd. A. R. Khan, Hyderabad Academy, Begumpet, Deccan, India (read by Dr. Russell).

11. "The Spectrum of a Perseid Meteor of 1949," John A. Russell, University of Southern California, Los Angeles, California.

12. "Subsurface Anomalies at the Barringer Meteorite Crater," Lincoln LaPaz, University of New Mexico, Albuquerque.

*13. "The Toluca, Mexico, Siderite (ECN = +0997,194)," Carl W. Beck, University of New Mexico, Albuquerque (read by Dr. LaPaz).

14. "The Glorieta Mountain, New Mexico, Siderite (ECN = +1058,356)," Carl W. Beck, Lincoln LaPaz, & Ralph G. Stevenson, Jr., University of New Mexico, Albuquerque (read by Dr. LaPaz).

15. "Meteoritical Great-Circle Problems," Frederick C. Leonard.

Morning Session, September 6

16. "The Helium Contents of Metallic Meteorites," Carl August Bauer, University of Michigan, Ann Arbor.

17. "Air Drag on Cubes at Mach Numbers 0.5 to 3.5," John S. Rinehart.

18. "The Hishikari, Japan, Achondrite (ECN = ∓1305,317)," Carl W. Beck, Lincoln LaPaz, & Louis H. Goldsmith, University of New Mexico, Albuquerque (read by Dr. LaPaz).

19. "Synthetic Schreibersite," John Davis Buddhue, 99 S. Raymond Av., Pasadena 1, California (read, at the author's request, by Dr. Leonard).

*20. "Fire from Heaven," C. C. Wylie, State University of Iowa, Iowa City (read by Dr. Bauer).

*21. "Meteor or Meteoric Cloud," C. C. Wylie (read by Dr. Bauer).

Afternoon Session, September 6

*22. "The Yonozu, Japan, Chondrite (ECN = ∓1394,380)," Carl W. Beck & Ralph G. Stevenson, Jr. (read by Dr. LaPaz).

23. "The Mino, Japan, Achondrite (ECN = ∓1367,354)," Carl W. Beck, Lincoln LaPaz, & Louis H. Goldsmith (read by Dr. LaPaz).

24. "A Preliminary Report on Indian Ruins Discovered Near the Crest of the Barringer Meteorite Crater," Lincoln LaPaz.

*25. "Cohenite Inclusions in Meteoritic Irons," Edward P. Henderson & Stuart H. Perry, U. S. National Museum, Washington, D. C. (read by Dr. Russell).

26. "An Application of the Theory of Atomic Clouds to an Estimate of the Energy of the Podkamennaya Tunguska, Siberia, Meteoritic Fall," Lincoln LaPaz.

At the close of the Tuesday-morning session, Dr. Leonard proposed that the Society recommend to the proper federal authorities that the name of Meteor Crater be changed officially to the "Barringer Meteorite Crater" in honor of the pioneering efforts of the late D. M. Barringer in maintaining and defending the hypothesis of its meteoritic origin. The members present unanimously approved this proposal.

The Society dinner, held at the Museum, followed the sessions of the second day. The guest speaker for the occasion was Assistant Director E. D. McKee of the Museum, who provided a thrilling diversion from meteoritics with an illustrated lecture on "shooting the rapids" down the Grand Canyon of the Colorado River. Dr. C. O. Lampland of the Lowell Observatory concluded the evening program with a showing of motion pictures of solar prominences filmed at the Harvard College Observatory Station at Climax, Colorado.

The third and final day of the meeting was spent at the Barringer Meteorite Crater with those present as the guests of its owners, the Standard Iron Company of Philadelphia, and its Curator, Mr. Theodore E. Johnson, and Mrs. Johnson. The morning hours were devoted to a general exploration of the Crater from its floor to areas well down on its outer slope. A thoroly enjoyed picnic lunch was eaten on a "promontory" overlooking the interior of the Crater.

The closing session was held at the luncheon site on the Crater rim. After brief comments on the past, present, and future of the Crater by Messrs. Brady,

Johnson, and Leonard, Dr. A. S. King delivered his report as the retiring President of the Society. Dr. King outlined the notable advances in meteoritics during the 4 years of his administration and expressed to President-elect L. F. Brady, Curator of Geology at the Museum of Northern Arizona, his best wishes and his confidence that the progress of meteoritics would continue unabated thruout President Brady's administration.

Upon the completion of Dr. King's report, Dr. Leonard expressed the thoughts in the minds of all present, when he paid eloquent tribute to the steadfast and capable services of Dr. King during a critical 4-year period in the life of the Society.

The 13th Meeting closed with a well-deserved vote of thanks to the Museum of Northern Arizona and its Directors, to Curator and Mrs. Johnson of the Barringer Meteorite Crater, and especially to President-elect Brady for the unstinting efforts that made the meeting such a memorable occasion.

Meteoritical Great-Circle Problems*

FREDERICK C. LEONARD
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7. *Introduction and Abstract.*—This paper is simply a continuation of that entitled "Trigonometric Criteria for Determining whether Meteoritic Falls Lie on the Same Great Circle" and published in *C.M.S., P. A.*, **58**, 350-5, August, 1950—so much so, in fact, that all the sections, figures, equations, and notes of the present paper are numbered in direct succession to those of its predecessor.

The current paper is divided into the following 9 parts: (7) introduction and abstract; (8) determination of the latitude of any point Q of given longitude, and of the longitudes of the 2 points, Q and Q', of given latitude, on the great circle; (9) determination of the angle between the meridian passing thru any point Q on the great circle, and the great circle; (10) and (11) methods of determining the coördinates of points T_i separated by intervals of $n°$ along the great circle; (12) determination of the bearing of point S from point R [*v.* §5 of the earlier paper], and *vice versa;* (13) determination of the coördinates of the *common nodes* of 2 great circles; (14) determination of the inclination i_{12} of 2 great circles to each other; and (15) determination of the coördinates of the points on 2 great circles 90° from their common nodes. As in the preceding paper, a number of subsidiary topics are discussed in the notes.

8. *Determination of the Latitude of any Point Q of Given Longitude, and of the Longitudes of the 2 Points, Q and Q', of Given Latitude, on the Great Circle.*—If the longitude (λ_Q) of any point Q on the great circle is given, its latitude (ϕ_Q) can be found merely by substituting its coördinates for those of point A in the equation of the great circle ((2) of §2 of the preceding paper) and solving for $\tan \phi_Q$. The result is

$$\tan \phi_Q = -\cos (\lambda_P - \lambda_Q) \operatorname{ctn} \phi_P. \tag{29}$$

Similarly, if the common latitude (ϕ_Q) of 2 points, Q and Q' on the great circle, equidistant from its vertices, is given, their longitudes (λ_Q and $\lambda_{Q'}$) can be calculated from the expressions

*"Introduction and Abstract" (§7) read at the 13th Meeting of the Society, Flagstaff and Barringer Meteorite Crater, Arizona, 1950 September 5-7.

$$\cos(\lambda_P - \lambda_Q) = \cos(\lambda_Q' - \lambda_P) = -\tan\phi_P \tan\phi_Q. \tag{30}$$

Obviously, from (30), the 2 points are coincident with each other and with a vertex of the great circle if $\phi_Q = \pm(90^\circ - \phi_P)$.

9. *Determination of the Angle between the Meridian Passing thru any Point Q on the Great Circle, and the Great Circle.*—The angle Q between the meridian passing thru any point Q on the great circle, and the great circle—*i.e.*, the azimuth or bearing of the latter at point Q—can readily be determined from right triangle CVQ (Fig. 2, §4), which is right-angled at vertex V and in which the angle at pole $C = \lambda_Q \sim \lambda_V$,[13] side $CV = 90^\circ - \phi_V$, and side $CQ = 90^\circ - \phi_Q$. The result, which follows at once from the appropriate right-triangle formula, is

$$\tan Q = \csc\phi_Q \operatorname{ctn}(\lambda_Q \sim \lambda_V). \tag{31}$$

The bearing of the great circle at point B can be obtained, of course, from (6) of §3, but that equation is usually less convenient than (31) for this particular purpose, inasmuch as (6) entails a knowledge of the coördinates of another *general point* (A) on the great circle as well as the evaluation of an *auxiliary angle* (G).

10. *Determination of the Coördinates of Points T_i Separated by Intervals of n° along the Great Circle: First Method.*—Suppose that it is desired to find the coördinates of points T_i along the great circle, the interval (*i.e.*, the angular distance) between any 2 successive points being n° and the coördinates, λ_Q, ϕ_Q, of one of the points, Q, being given. In right triangle CVQ (§9), the angular distance d_Q of point Q from vertex V is determinable by either of the formulas

$$\tan d_Q = \tan(\lambda_Q \sim \lambda_V)\cos\phi_V = \operatorname{ctn}\phi_Q \cos Q. \tag{32}$$

Let kn°, in which k is either a positive or a negative integer, be the angular distance measured along the great circle from point Q to any other point T on it, whose coördinates, λ_T, ϕ_T, are required. The angular distance d_T of point T from vertex V is evidently

$$d_T = d_Q + kn^\circ. \tag{33}$$

In right triangle CVT, which is right-angled at vertex V, the adjacent sides are $CV = 90^\circ - \phi_V$, and $VT = d_T$, whereas angle $VCT = \lambda_V \sim \lambda_T$, and side $CT = 90^\circ - \phi_T$; hence, from the appropriate right-triangle formulas,

$$\tan(\lambda_V \sim \lambda_T) = \tan d_T \sec\phi_V, \tag{34}$$

and

$$\tan\phi_T = \tan\phi_V \cos(\lambda_V \sim \lambda_T), \tag{35}$$

from which the coördinates, λ_T, ϕ_T, follow.

If point Q is coincident with vertex V, $d_Q = 0$ and $d_T = kn^\circ$. Each solution of (34) then yields the longitudes of 2 equidistant points from vertex V, one east and the other west of it, whose common latitude is fixed by (35).

11. *Determination of the Coördinates of Points T_i along the Great Circle: Second Method.*—The coördinates of any point T on the great circle can be determined directly—*i.e.*, without recourse to those of vertex V—if, in triangle QCT, the angle at point Q—which shall here be designated as angle Q—is known.[14] In this triangle, the including sides, $CQ = 90^\circ - \phi_Q$ and $QT = kn^\circ$, likewise are known; hence, the angle at pole $C = \lambda_T \sim \lambda_Q$, and side $CT = 90^\circ - \phi_T$, which involve the coördinates of point T, can be found from the 3 fundamental formulas of spherical trigonometry. If the substitutions

$$j \sin J = \sin kn^\circ \cos Q, \tag{36}$$

and

$$j \cos J = \cos kn^\circ, \tag{37}$$

from which

$$\tan J = \tan kn^\circ \cos Q, \tag{38}$$

be made in those formulas, then the following equations, which effect the solution, result:

$$\tan (\lambda_T \sim \lambda_Q) = \tan Q \sin J \sec (\phi_Q + J), \tag{39}$$

$$\tan \phi_T = \tan (\phi_Q + J) \cos (\lambda_T \sim \lambda_Q). \tag{40}$$[15]

12. *Determination of the Bearing of Point S from Point R, and Vice Versa.*—This section pertains to §§5 and 6, in which points R and S are defined and their relations to each other and to the great circle are discussed. It may be desired to find the bearing of point S from point R, and *vice versa*, as well as their angular or linear distance apart. The bearing of each point from the other can be ascertained by solving for the angles at points R and S in triangle CRS (Fig. 3, §5), in which all 3 sides, $CR = 90^\circ - \phi_R$, $CS = 90^\circ - \phi_S$, and $RS = d$, and likewise angle $RCS = \lambda_R \sim \lambda_S$, either are given or are determinable from the equations of §§5 and 6. The formulas for the tangents of the half-angles of the general spherical triangle, which need not be reproduced here, may readily be adapted for the purpose, or the following mode of solution may be employed.

First, in quadrantal triangle PCS, the angle at point S is calculable by (26) of §6. This angle S, or its supplement, equals the bearing of point R from point S, according as point R is north or south of point S (*v.* points R_1 and R_2, Fig. 3, §5). Next, in triangle CRS, to find the angle at point R (= angle CRS), or angle R, which equals the bearing of point S from point R, let

$$k \sin K = \cos \phi_S \cos (\lambda_R - \lambda_S), \tag{41}$$

and

$$k \cos K = \sin \phi_S; \tag{42}$$

then

$$\tan K = \operatorname{ctn} \phi_S \cos (\lambda_R - \lambda_S), \tag{43}$$

and it follows from the 3 fundamental formulas of spherical trigonometry that

$$\tan R = \tan (\lambda_R \sim \lambda_S) \sin K \sec (\phi_R + K). \tag{44}$$[16]

13. *Determination of the Coördinates of the Common Nodes of 2 Great Circles.*—It may be useful to find the coördinates of the points in which 2 great circles of north poles P_1 and P_2 intersect. These points shall be called the *common nodes* of the great circles, in order to distinguish them from the pairs of points in which the great circles intersect the equator, which shall be termed the *equatorial nodes* of the great circles. The *ascending equatorial node* of each great circle shall be defined as the node where a point, conceived to move along the great circle from east to west, crosses the equator from south to north, and the *descending equatorial node* as the opposite node. Denote the ascending equatorial nodes of the great circles by N_1 and N_2, node N_1 being the more easterly one, and arc N_1N_2 being $< 180^\circ$, and the common node of the great circles that is the *closer* one to nodes N_1 and N_2 by N_{12}; denote also the longitudes of nodes N_1 and N_2 by λ_1 and λ_2; the coördinates of node N_{12} by λ_{12}, ϕ_{12}; and the inclinations of the great circles to the equator and to each other by i_1, i_2, and i_{12}, respectively. The problem is to determine λ_{12}, ϕ_{12}, the coördinates of common node N_{12}.[17]

Evidently the longitude of the ascending equatorial node of each great circle equals the longitude of its north pole plus 90°, or the longitude of its north vertex minus 90°, whereas the inclination of each great circle to the equator equals the colatitude of its north pole or the latitude of its north vertex, and the inclination of the 2 great circles to each other (i_{12}) equals the angular distance P_1P_2 between their north poles, which is readily computable from the coördinates of those poles (*cf.* n. (8) and n. (6), §3, *ante*, and *v.* §14, *post*).

Two (2) cases arise in this problem, which are illustrated by Figs. 4 and 5.

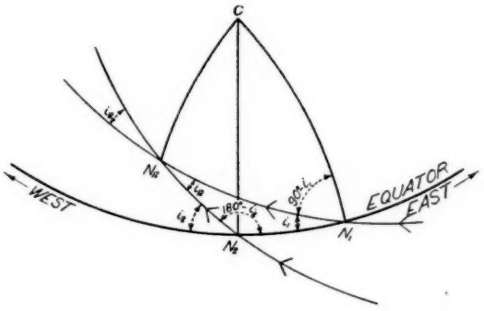

FIG. 4

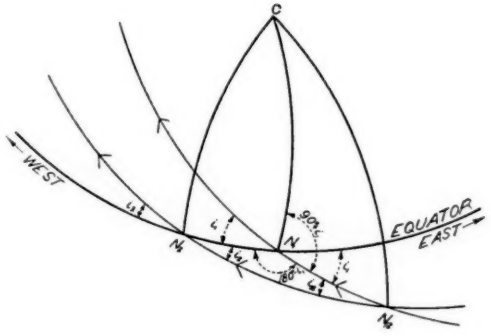

FIG. 5

In the first case (Fig. 4), $i_1 < i_2$, node N_{12} is west and north of node N_2, and the angles at nodes N_1, N_2, and N_{12} in triangle $N_1N_2N_{12}$ respectively equal i_2, $180° - i_2$, and i_{12}. In the second case (Fig. 5), $i_1 > i_2$, node N_{12} is east and south of node N_1, and the angles at nodes N_{12}, N_1, and N_2 in triangle $N_{12}N_1N_2$ respectively equal i_{12}, $180° - i_1$, and i_2.[18] In both cases, all 3 angles in the triangle either are known or are determinable, and side $N_1N_2 = \lambda_2 - \lambda_1$ likewise is known. It is necessary, however, to find either side N_1N_{12} or side N_2N_{12}—*e.g.*, the former.

In the first case (Fig. 4), in which $i_1 < i_2$, side N_1N_{12} can be obtained from

triangle $N_1N_2N_{12}$, in which the angles, i_1 and $180° - i_2$, and the included side, $N_1N_2 = \lambda_2 - \lambda_1$, will be utilized for the purpose.[19]

If

$$l \sin L = \sin i_2 \cos (\lambda_2 - \lambda_1), \tag{45}$$

and

$$l \cos L = -\cos i_2, \tag{46}$$

from which

$$\tan L = -\tan i_2 \cos (\lambda_2 - \lambda_1), \tag{47}$$

be substituted in the 3 fundamental formulas of spherical trigonometry "for angles," as applied to angle i_{12} and side N_1N_{12}, it can be showed that

$$\tan N_1N_{12} = \tan (\lambda_2 - \lambda_1) \sin L \csc (L + i_1), \tag{48}$$[20]

and

$$\tan i_{12} = -\tan (L + i_1) \sec N_1N_{12}. \tag{49}$$

In quadrantal triangle N_1CN_{12} (Fig. 4), 2 sides, side $CN_1 = 90°$, side N_1N_{12}, which is now determinable from the foregoing equations, (45)-(48), and the included angle, $N_{12}N_1C = 90° - i_1$, are known, from which angle $N_1CN_{12} = \lambda_{12} - \lambda_1$, and side $CN_{12} = 90° - \phi_{12}$, can be found. Application of the appropriate formulas to these unknown parts, which contain the desired coördinates, gives

$$\tan (\lambda_{12} - \lambda_1) = \tan N_1N_{12} \cos i_1, \tag{50}$$[21]

and

$$\tan \phi_{12} = \tan i_1 \sin (\lambda_{12} - \lambda_1). \tag{51}$$

In the second case (Fig. 5), in which $i_1 > i_2$ and node N_{12} is east and south of node N_1, the solution is the same, except that i_1 and i_2 are interchanged in the first 5 equations of the development, thus giving rise to a different auxiliary angle, namely M, and, in quadrantal triangle $N_{12}CN_1$, the angle at node N_1 (*i.e.*, angle $N_{12}N_1C = 90° + i_1$. The equations that effect the solution, and which can be written down by analogy with (45)-(51), are as follows:

$$m \sin M = \sin i_1 \cos (\lambda_2 - \lambda_1), \tag{52}$$

$$m \cos M = -\cos i_1, \tag{53}$$

$$\tan M = -\tan i_1 \cos (\lambda_2 - \lambda_1), \tag{54}$$

$$\tan N_{12}N_1 = \tan (\lambda_2 - \lambda_1) \sin M \csc (M + i_2), \tag{55}$$

$$\tan i_{12} = -\tan (M + i_2) \sec N_{12}N_1, \tag{56}$$

$$\tan (\lambda_1 - \lambda_{12}) = \tan N_{12}N_1 \cos i_1, \tag{57}$$

and

$$\tan \phi_{12} = -\tan i_1 \sin (\lambda_1 - \lambda_{12}). \tag{58}$$[22]

14. *Determination of the Inclination i_{12} of 2 Great Circles to Each Other.*— The angle of inclination i_{12} between 2 great circles—which is equal obviously to the dihedral angle between their planes and to the angular distance P_1P_2 between their north poles—is, as was remarked in the second paragraph of §13, readily calculable from the coördinates of those poles; it can be determined also by means of (49) or (56)[23] of §13, but it can be found probably most easily and directly by use of the cosine formula as applied to angle i_{12} in triangle $N_1N_2N_{12}$ (Figs. 4 and 5, §13), which yields

$$\cos i_{12} = \cos i_1 \cos i_2 + \sin i_1 \sin i_2 \cos (\lambda_2 - \lambda_1). \tag{59}$$

This shows that i_{12} is a function of only i_1, i_2, and $\lambda_2 - \lambda_1$, as would naturally be expected.

An interesting case presents itself when $i_1 = i_2 = i$. In this case, (59) reduces to

$$\cos i_{12} = \cos^2 i + \sin^2 i \cos (\lambda_2 - \lambda_1), \tag{60}$$

from which it is apparent that, when $\lambda_2 - \lambda_1 = 0°$, $i_{12} = 0°$ (*i.e.*, the great circles are coincident); when $\lambda_2 - \lambda_1 = 90°$, $i_{12} = \cos^{-1} \cos^2 i$; and when $\lambda_2 - \lambda_1 = 180°$, $i_{12} = 2i$ (this being the maximum inclination of the 2 great circles to each other, which results when the ascending equatorial node of one coincides with the descending equatorial node of the other).[24]

15. *Determination of the Coördinates of the Points on 2 Great Circles 90° from their Common Nodes.*—Consider the points on each of 2 great circles, 90° from their common nodes.[25] The determination of the coördinates of these 90° points is manifestly but a special case of the general problem discussed in §§10 and 11 as applied to points on *two* (2) great circles instead of *one*, in which the 90° points on each great circle are points T_i ($i = 1, 2$), the angular interval $n°$ (between a common node and a 90° point) is 90°, and one or the other of the common nodes, N_{12} or N_{12}', is the point Q. Obviously either method of solution (§10 or §11) can be employed to evaluate the coördinates of the 90° points, but since the method of §11 is probably the more convenient, it will be used here.

Denote the 90° points on the *first* great circle by U and U', and their coördinates by λ_U, ϕ_U, and $\lambda_{U'}$, $\phi_{U'}$, respectively, point U being the point 90° to the *west* of node N_{12}. Evidently, since points U and U' are antipodal, $\lambda_{U'} = \lambda_U + 180°$, and $\phi_{U'} = -\phi_U$. The coördinates of point U can readily be determined from quadrantal triangle $N_{12}CU$, in which the angle at node N_{12} (= angle $CN_{12}U$), which shall be called angle N_{12}, can be evaluated by use of an equation of the type of (31) of §9, *viz.*,

$$\tan N_{12} = \csc \phi_{12} \operatorname{ctn} (\lambda_{12} \sim \lambda_V), \tag{61}$$[26]

and in which the including sides are $CN_{12} = 90° - \phi_{12}$, and $N_{12}U = 90°$. Application of the appropriate formulas to angle $N_{12}CU = \lambda_U - \lambda_{12}$, and side $CU = 90° - \phi_U$, which contain the desired coördinates, yields, in view of (61):

$$\tan (\lambda_U - \lambda_{12}) = -\tan N_{12} \csc \phi_{12} = -\csc^2 \phi_{12} \operatorname{ctn} (\lambda_{12} \sim \lambda_V), \tag{62}$$

$$\tan \phi_U = -\operatorname{ctn} \phi_{12} \cos (\lambda_U - \lambda_{12}). \tag{63}$$[27]

In exactly the same way, and by means of quadrantal triangle $N_{12}CW$, the coördinates of the 90° points, W and W', on the *second* great circle can be deduced. The equations, which can be written down by analogy with (61)-(63), will be omitted.

NOTES

[13] The symbol ($\sim$) means the algebraic difference between 2 quantities without regard to the sign of their difference—*i.e.*, the *absolute value* of the algebraic difference between 2 quantities.

The coördinates of vertex V are, obviously, $\lambda_V = \lambda_P \pm 180°$ and $\phi_V = 90° - \phi_P$ ((10) and (11), §3).

[14] Whether the angle at point Q in triangle QCT—which equals the bearing of point T from point Q—is equal to the angle at that point in right triangle CTQ (§9), or to the *supplement* of the latter angle, depends upon the *order* in which points Q and T and vertex V lie along the great circle; this is, of course, easily determinable. To settle the question in any case, a sketch may be drawn.

[15] ϕ_T can be obtained directly, of course, from the cosine formula as applied to side $CT = 90° - \phi_T$, which gives

$$\sin \phi_T = \cos kn° \sin \phi_Q + \sin kn° \cos \phi_Q \cos Q. \tag{40a}$$

[16] After angles K and R have been evaluated by use of (41)-(44), the angular

distance d between points R and S can be computed directly by means of the formula

$$\tan d = \operatorname{ctn}(\phi_R + K)\sec R. \qquad (44a)$$

(*Cf.* §5.)

The *bearing* from each other of *any* 2 given points, A and B, on the great circle, or, for that matter, anywhere else on the sphere, can readily be found by solving for the angles at those points in triangle ACB, in which 2 sides (which equal the colatitudes of the points) and the included angle (which equals the difference in their longitudes) are known; furthermore, the *great-circle distance* between the 2 points can be determined by solving for the third side of the triangle; *v.* n. (6) of the earlier paper and the ref. therein cited.

[17] The coördinates of the opposite node, N_{12}', are, obviously, $\lambda_{12}' = \lambda_{12} + 180°$, $\phi_{12}' = -\phi_{12}$.

[18] In the first case, node N_{12} is the *ascending* common node of the second great circle with reference to the first, and the *descending* common node of the first great circle with respect to the second, whereas, in the second case, node N_{12} is the *descending* common node of the second great circle with reference to the first, and the *ascending* common node of the first great circle with respect to the second (*cf.* Figs. 4 and 5); in other words and in general, node N_{12} is the *ascending common* node of that great circle whose *ascending equatorial* node is the *closer* one of the 2 *ascending equatorial* nodes (N_1 and N_2) to node N_{12}.

[19] Either side N_1N_{12} or side N_2N_{12} can be found, of course, by application of the appropriate formula for the tangent of the half-side, but a simpler method of solution, and one that eventuates in the evaluation of angle i_{12} also, is the following.

[20] Evidently the value of $\tan N_1N_{12}$ can be taken from this equation—(48)—and substituted into (50), *post*, without evaluating side N_1N_{12} itself, if only the coördinates of node N_{12} (*v.* (50) and (51), *post*) are desired.

[21] *V.* n. (20), *ante*.

[22] If $i_1 = i_2$, the 2 sets of equations, (45)-(51) and (52)-(58), are identical; either set can then be employed to find the coördinates of node N_{12}.

[23] And likewise from the coördinates of the corresponding points on the 2 great circles that are 90° from their common nodes (*v.* §15, n. (25), *post*).

[24] The results of this section can be deduced also from triangle CP_1P_2, in which the sides opposite the 3 poles, C, P_1, and P_2, are respectively i_{12}, i_2, and i_1, and the angle at pole C (= angle P_1CP_2) $= \lambda_2 - \lambda_1$, if the cosine formula be applied to side i_{12}.

[25] Evidently the angular distance between corresponding 90° points on 2 great circles—which might be called their "mutual vertices"—is equal to the inclination of the great circles to each other, i_{12} (*cf.* §§13 and 14).

[26] Actually only $\tan N_{12}$ need be determined, since its value can be substituted directly into (62), *post*.

[27] The first 2 members of (62), and likewise (63), result from (39) and (40) of §11, when the coördinates of point U and node N_{12} are substituted for those of points T and Q, respectively; in this case, since $kn° = 90°$, auxiliary angle $J = 90°$ (*v.* (36)-(38)).

On the Identification and the Recovery of the Goose Lake, California, Siderite (ECN = + 1205,420)

Frederick C. Leonard

Department of Astronomy, University of California, Los Angeles

Abstract

Just to keep the record straight, and in justice to all concerned, the historical facts regarding the identification and the recovery of the Goose Lake, California, siderite, the fourth-largest known meteorite of the United States, are herein briefly repeated.

In *The Nininger Collection of Meteorites*, "a publication of the American

Meteorite Museum, Winslow, Arizona, 1950," by H. H. and Addie D. Nininger, under the heading of "Goose Lake," p. 109, the following statement appears:

"During the winter of 1938-39 the American Meteorite Laboratory received from Professor Earle G. Linsley and also from Dr. F. C. Leonard small samples of an iron meteorite for verification. These samples were said to have come from a very large block of iron in northeastern California and had been supplied by Clarence A. Schmidt who had found the iron while deer hunting. In the spring of 1939, accompanied by Mr. Schmidt as guide, we re-discovered the large iron. It was delivered to the U. S. National Museum, having been found on U. S. Government land."

Just to keep the record straight, I want to state that no samples of the Goose Lake, California, siderite were ever forwarded by me to H. H. Nininger "for verification" or for any other purpose. The circumstances of the identification and the recovery of that great iron are set forth in detail in my paper entitled, "The Goose Lake Siderite: The Largest Known Meteorite of California," and published in *The Griffith Observer*, **4**, No. 1, 1-8, 6 figs., January, 1940, to which reference should be made for the facts in the case and from which but a single quotation (of the first 2 paragraphs) must here suffice.

"Thru the coöperation of several scientists, mostly Fellows of the Society for Research on Meteorites [now The Meteoritical Society], the largest meteorite discovered up to date in California, and probably the fifth-largest specimen known to have fallen within the United States [the fourth-largest, if the semi-mythical Port Orford, Oregon, siderolite is excluded], has recently been identified and recovered. On October 13, 1938, Messrs. Joseph Secco, Clarence A. Schmidt, and Ira Iverson, of Oakland, California, while hunting deer about 2 miles west of Goose Lake and a mile and a quarter south of the California-Oregon state line, in northeastern Modoc County, accidentally came upon a massive, irregular body of metal, seemingly natural iron, which Mr. Secco was the first to reach and which Mr. Schmidt at once suspected of being a meteorite. News of the discovery was soon conveyed to Professor Earle G. Linsley, the Director of the Chabot Observatory in Oakland, and subsequently to Dr. Dinsmore Alter, the Director of the Griffith Observatory in Los Angeles. A small fragment, weighing only a few grams, and a couple of snapshots of the specimen were forwarded by Mr. Schmidt to Dr. Alter, who promptly communicated with the writer. At the Griffith Observatory, in Dr. Alter's presence, the writer etched the surface of this fragment with dilute nitric acid and detected thereupon the Widmanstätten crystallization figures, which, in spite of the diminutive size of the fragment, clearly indicated that it was a piece of a nickeliferous-iron meteorite (or siderite), apparently of the medium-octahedrite variety. Several specks were detached from the fragment and taken to Dr. Robert W. Webb of the Department of Geology of the University of California at Los Angeles, who applied to them the extremely sensitive dimethylglyoxime and potassium-mercuric-thiocyanate tests for nickel, with pronounced positive reactions. In view of the photographs and the results of the chemical tests, no doubt remained that the great iron that Messrs. Secco, Schmidt, and Iverson had discovered was a magnificent meteorite.

"Early in April, 1939, the writer interviewed Mr. Schmidt in Berkeley and learned from him that the meteorite was located about 35 miles north of Alturas, the principal town and county seat of Modoc County, in the Modoc National Forest. Mr. Schmidt estimated from memory that the dimensions of that part of the meteorite above the level of the ground were 4 by 3 by 1 ft. (After the meteorite was removed from its place of fall, the dimensions were measured as

3 ft. 10 in., by 2 ft. 4½ in., by 1 ft. 8 in.) Later in April, Dr. H. H. Nininger, the Director of the American Meteorite Laboratory of Denver, Colorado, accompanied by Mrs. Nininger, was in California on a lecture tour. In the course of his sojourn in Los Angeles, the writer told him about the meteorite and suggested that he too, when in the Bay region a few days afterward, interview Mr. Schmidt in regard to the specimen. He did so, and the result of that interview was that he, Mrs. Nininger, Professor Linsley, and Mr. Schmidt all hurriedly left to visit the meteorite, and reached it on April 29, 1939. They were quickly followed by Dr. Webb and the writer, who departed from Los Angeles on May 1 and arrived at the meteorite on May 2. On May 3 and 4, a party including Dr. and Mrs. Nininger, Dr. Webb, and the writer, equipped with horses and wagon and a motor truck, removed the meteorite from its place of fall and took it to Alturas, where it was publicly exhibited for a few hours, night and morning, and whence, on May 5, it was transported in an automobile truck, by Professor Linsley and an assistant, to the San Francisco Bay region. There it was shown briefly at the Students' Observatory of the University of California in Berkeley, and for a week (May 7 to 14), at the Chabot Observatory in Oakland, and then was conveyed to the Golden Gate International Exposition in San Francisco Bay, where it remained continuously on exhibition and attracted the attention of countless persons until the fair ended on October 29, 1939."

In due justice to all concerned, the credit for the recovery of the Goose Lake meteorite should go to and should be shared equally by Earle G. Linsley, Addie D. and H. H. Nininger, Robert W. Webb, and me—the 5 members of the expedition that recovered the mass and made it available for public exhibition at the Golden Gate International Exposition in San Francisco Bay during the 2 seasons of 1939 and 1940, before it was transported to its permanent repository, the United States National Museum in Washington, D. C.

A Note on the Origin of Tektites: A Correction

The undersigned recently published, in *Trans. Roy. Soc. S. Aust.*, **73**, (1), 7-21, 16 Dec., 1949, a paper entitled "Australites, Part V: Tektites in the South Australian Museum, with Some Notes on Theories of Origin." In that paper, p. 20, par. 2, he made an unpardonable error, doing an injustice both to Professor Lincoln La Paz and to Professor Virgil E. Barnes. He stated that "La Paz himself leans definitely to the lightning hypothesis." He wrote that he quoted from *Abs. Geol. Soc. Am.*, p. 1919, 1940. Actually, the quotation was from Virgil E. Barnes. Sincere apologies are hereby tendered to both gentlemen. Barnes leans to the lightning theory of the origin of tektites, or did so in 1940; La Paz, on the other hand (*C.S.R.M.*, **2**, 28-34; *P. A.*, **46**, 224-30, 1938), has vigorously opposed the theory of the fulguritic origin of tektites. The writer begs to correct his error.

CHARLES FENNER

South Australian Museum, Adelaide, South Australia, 1950 August 30

Change in the Format of C.M.S., January, 1951

The Editor of the Society is pleased to announce that, by arrangement with the Editor and the publishers of POPULAR ASTRONOMY, commencing with the issue for January, 1951, when a new volume, both of *P. A.* (**59**) and of *C.M.S.*

(5), will begin, these CONTRIBUTIONS will be printed in 10-point type in the principal part of the magazine.

President of the Society: L. F. BRADY, 922½ Forest Avenue, Tempe, Arizona
Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

The A.A.V.S.O. at Harvard. The 39th Annual Meeting of the A.A.V.S.O. was held at the Harvard College Observatory on Friday and Saturday, October 13 and 14, 1950. The Council met on Friday afternoon, with 11 members and 3 invited guests present. Twelve new annual members were elected, and the application of Chrysostomos Drakakis to transfer from annual membership to life membership was approved. Dr. Curvin H. Gingrich was elected an Honorary Member of the Assocation, in recognition of his years of service to the AAVSO, and Dr. Lawrence N. Upjohn was elected a Patron Member in appreciation of his generous support of the Association's activities. The names of the new annual members follow:

Jack R. Blundell, Lobenthal, South Australia
H. S. Jerabek, 850 21st Avenue S. E., Minneapolis 14, Minnesota
Clarence E. Johnson, 102 State Street, Schenectady 5, New York
Charles H. LeRoy, R.D. No. 11, Pittsburgh 15, Pennsylvania
Emil Leutenegger, Ruegerholzstrasse 17, Frauenfeld, Switzerland
Gary Motley, 24 Crane Avenue, West Caldwell, New Jersey
Jean Nicolini, C.P. 17B, Sao Paulo, Brazil
William H. O'Sullivan, 405 Clayton Street, San Francisco 17, California
Argentino Romaña, Julio A. Roca 255, Resistencia (Chaco) Argentina
Richard M. Thompson, Star Route, Delmar, New York
Milford W. Wall, 12 Euston Street, Brookline, Massachusetts
Hoy J. Walls, 6503 Georgia Street, Chevy Chase, Maryland

On Friday evening, the Observatory Library was well filled with members and guests who came to hear Dr. Carl W. Gartlein of the Department of Physics of Cornell University. Dr. Gartlein told of some of his latest researches on auroral problems, and particularly stressed the hydrogen theory of the origin of aurorae. He illustrated his lecture with many beautiful color slides and movies of auroral displays.

The members of the Association gathered in the Library at 10 A.M. Saturday for the Annual Business meeting and session for papers. The result of the election of new Council members was announced: Margaret H. Beardsley, Ferdinand Hartmann, Helen S. Hogg, and Harold B. Webb were elected for the term 1950-52. At the noon meeting of the Council the officers of the past year were all re-elected as follows:

President	Neal J. Heines
First Vice-President	Martha E. Stahr
Second Vice-President	Donald H. Menzel
Recorder	Margaret W. Mayall
Secretary	Clinton B. Ford
Treasurer	Percy W. Witherell

After the reports of the Secretary and Treasurer were read and approved, the 19th Annual Report of the Recorder was presented. This report will be printed in full in "Variable Comments," but I will mention a few items here.

Nearly 52,000 observations of variable stars were contributed during the year by 131 observers. The observations came from 17 countries scattered over the world, with the observers outside the United States contributing 40 per cent of the total. Cyrus Fernald held his place as top observer for the year 1949-50 with 6,537 observations. His total observing time was 109 hours and 35 minutes on 125 nights, which makes an average of 1 minute per star. Second place is held by Reginald P. de Kock of South Africa, with 5,350 observations. Next in order are Leslie C. Peltier of Delphos, Ohio, with 2,504 observations; Edward Oravec of New York with 2,151; and Paul Ahnert of Sonneberg, Germany, with 2,067 observations. Ten observers contributed between 1,000 and 2,000 observations during the year: Lacchini, Italy, 1,985; Drakakis, Greece, 1,933; Greenley, New Jersey, 1,713; Hartmann, New York, 1,623; Renner, Ohio, 1,562; Bogard, New Jersey, 1,326; Peter, Switzerland, 1,163; Pearcy, Indiana, 1,138; Rosebrugh, Connecticut, 1,082; and Galbraith, California, 1,048.

The President, Mr. Heines, presented a fine report of the work of the Solar Division, of which he is Chairman. Solar activity is slowly declining, and the consensus is that the next minimum in the sunspot cycle will occur late in 1954 or early in 1955—but the Solar Division activity continues to increase. Among its projects are sunspot counts, studies of the granular surface, and color in sunspots, unusual spot configurations, the foreshortening project, sunspot delineation, and area measurements; also studies of solar radiations and migratory birds.

The Auroral work is now a separate section of the AAVSO, and Donald Kimball has been appointed Chairman. Miss Farnsworth has retired as Chairman of the Occultations Committee, and Mrs. Hartness Beardsley succeeds her. Mrs. Beardsley reported 91 occultations sent in by 18 observers during the year.

The Chart Curator, Richard Hamilton, reported 2,582 blueprint charts and 22 AAVSO Star Atlases were distributed to observers during the year. This was in answer to 161 requests, 29 of them from 22 observers in 15 foreign countries.

A fine program of papers was presented during the morning and afternoon sessions: "On a Method of Checking Apparent Sunspot Colors with Standard Filters," James Bartlett; "Light Fluctuations of Zinner 1256," Ralph N. Buckstaff; "Fifty Years of Sunspots at Mount Holyoke," Alice Farnsworth; "Trying to Observe Lunar Meteors," John Holloway; "A Study in the Life of Sunspot Groups," Neal J. Heines; "The Variable Star Zinner 402," Robert M. Greenley; "Letter from Berlin," Marjorie Williams; "How to Make Your Observing Time Count the Most," Cyrus Fernald; "Pen and Graph Paper," Jeremy Knowles; "Comparison Study of Projection and Direct Sunspot Observations," Margaret Beardsley; "Area Relationships in Long-Period Light Curves," Clinton Ford; "Barlows," and "Visibility of Fine Planetary Detail," David W. Rosebrugh.

At the close of the afternoon session, the members and their guests adjourned for tea in the Observatory Residence at the invitation of Dr. and Mrs. Shapley. At seven o'clock they gathered again at the Hotel Continental for the

Annual Dinner. With Miss Farnsworth presiding, the meeting came to a fine close, with a talk by Mr. Rosebrugh on the trials and tribulations of making an index to "Variable Comments," a hint of some new applications of optics to astronomy, by Dr. James Baker, and a movie by Mr. Ford, showing us what we looked like at the meetings of 1947 and 1949. The final item on the program was Dr. Shapley's annual talk on the "Highlights of the Year," which were:

1. The Ungava Peninsula meteor crater (northern Quebec), which, with a diameter of 2½ miles, is three times larger than the Arizona Meteor Crater, and by far the largest known.

2. The Great Smog resulting from the forest fires in northern Alberta and the Mackenzie River area and spreading over all the northern and eastern states, across the ocean into Europe, spoiling the lunar eclipse, stopping astronomical observations for several days and producing blue, yellow, and violet suns.

3. The work of O. J. Eggen at the Lick Observatory on precise photometry and magnitudes of the nearby stars.

4. The Centennial at Harvard of the first astrophotograph, made July 16-17, 1850, with the 15-inch equatorial at the Harvard Observatory.

5. New measure of the diameter of Pluto, showing that its size is scarcely half as big (in diameter) as previously measured, and yielding the mass and volume about one-tenth that of the earth, and an intermediate surface brightness (albedo) indicative that the surface is covered with the snow of various molecules, dirtied by the dust of comets and meteors.

6. The planning of a high altitude astronomical and physical observatory in the Himalayas by the Indian Government, probably to be installed in north Sikkim at an altitude of 17,000 feet, in a pressurized building, with the scientific colony being mostly at an altitude of 12,000 feet, all this development under the Meteorological Department of the Indian Government.

7. The new orbit of the asteroid Eros, worked out by Eugene Rabe at the Cincinnati Observatory, which has yielded new values of the masses for the inner planets, a new (dynamical) parallax of the sun that differs by one-tenth of one per cent from the trigonometric parallax derived by the Astronomer Royal in 1941, and yielding also a revision of the elements of the earth's orbit.

8. The bringing of the number of radio stars to fifty, chiefly the work of Dr. Ryle of Cambridge, England, assisted by the Australians and others.

9. Completion and first operation of the two-mirror Schmidt telescope, called the Schmidt-Cassegrain, by the University of St. Andrews (Professor Freundlich), with the installation of the 19-inch diameter instrument in the observatory of Mr. Mills at Dundee, Scotland, where satisfactory photographs over 4° fields were attained. The instrument differs in character from the ADH (Baker-Schmidt) telescope of Harvard, Dunsink, and Armagh (which is now nearing the African ports) in that the focus is behind the primary mirror rather than in front of it.

10. The demonstration by Harvard observers that the nearest star, Proxima Centauri, is a flare star, the fifth on record, and during the past twenty-five years, according to several hundred photographs, has exhibited a total of fifty flareups, indicating that perhaps these Class M dwarf red stars are all flare stars, and that the flaring, similar to the flares on the surface of the sun, are a significant phenomenon connected with the evolution of red low-luminosity dwarfs.

In addition there was mention made of important personnel changes in astronomy (Struve, Strömgren, Deutsch), and of new work on the radial velocities of solar granulations and on the equatorial "bilge" (such as meteors, comet

debris, and star tails) that is becoming an important consideration in the study of close binaries. The lowlight of the year, not mentioned publicly at the dinner, was unquestionably the Velikovsky affair.

New Eclipsing Variable. A recent letter from Father O'Connell of Riverview College Observatory, New South Wales, tells of an eclipsing binary he has found that has an eclipse which probably lasts 17 or 18 years. The star is in the constellation Musca, and is C.P.D. —60° 3278, H.D. 306989, spectrum B3. The range in photographic magnitude is from 9.5 to 10.2. Father O'Connell thinks the period may be of the order of 200 years.

174535 *Nova Scorpii 1950.* Father O'Connell also sends some photographic observations of Sr. Haro's nova in Scorpius. He has some pre-discovery photographs on which the nova was of magnitude 8.5 on August 2. It reached 7.8 on August 5, and declined to fainter than 12.5 on August 29.

213843 *SS Cygni.* Another maximum of SS Cygni started the last of October. The first report received at AAVSO Headquarters was from Edward Upton, who caught it at 8.5 on October 31, with the AAVSO Post 6-inch refractor in Cambridge. The maximum is a wide one, and most of the observers have reported it. The star has been going through some rapid fluctuations. On at least two different occasions since the last real maximum, it has been somewhat brighter than 11th magnitude.

Variable Comparison Star. Cyrus Fernald reports that the 12.5 comparison star, about 0^m2 east and 0'.6 south of 005840 RX Andromedae, is variable. He gets a variation from 12.5 up to as bright as 11.0. Observers should use great care in their estimates of RX.

Observations received during September and October, 1950: Seventy-seven observers contributed 10,899 observations during these two months—5,963 in September and 4,936 in October.

	September—1950—October					September—1950—October			
Observer	No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.	No. Var.	No. Ests.
Adams	45	121	53	116	Estremadoyro, G. A.	..	..	3	3
Ahnert	..	..	26	167	Estremadoyro, V. A.	..	..	1	1
Ancarani	32	50	19	20	Fernald	274	661	299	764
Bicknell	17	222	6	33	Focas	..	..	16	30
Blunck	21	24	..	..	Ford	22	22	..	..
Bogard	54	81	63	123	Galbraith	35	199	36	119
Boone	16	16	..	..	Greenley	75	250	72	113
Buckstaff	30	111	22	76	Halbach	15	15	..	..
Bufkin	10	12	..	..	Hamilton	6	6	7	10
Cain	15	29	15	27	Hartmann	143	155	144	155
Charles	26	36	22	27	Herring	4	4	..	..
Cisler	1	1	1	2	Hiett	9	18	..	..
Cobb	..	..	3	12	Holloway	15	24	6	6
Cooke	..	..	32	36	Howarth	..	..	11	11
Costello	9	10	7	7	Jerabek	14	40	9	21
Cragg	122	122	133	146	Kato	32	132	..	..
Dafter	10	24	10	36	Kelly	13	18	11	11
Darling	15	17	..	..	Knowles	10	158	10	65
Darnell	3	12	1	6	de Kock	119	396	128	557
Davis	38	91	..	..	Lacchini	83	308	84	142
Diedrich, DeL.	2	2	2	4	Lankford	8	10	..	..
Diedrich, G.	2	2	2	4	Lee	19	30	..	..
Drakakis	23	71	15	65	Leutenegger	37	120	38	81
Elias	20	90	..	..					
Escalante	..	..	48	51					

Observer	September—1950—October No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	September—1950—October No. Var.	No. Ests.	No. Var.	No. Ests.
LeVaux	113	116	86	110	Renner	220	231	167	167
Meek	..	..	30	191	Rosebrugh	35	242	20	120
Melville	13	53	12	48	Schoenke	2	2	..	..
Miller	..	..	46	66	Schulte	8	8	6	7
Milone	22	43	..	..	Snow	..	..	10	10
Morrisby	12	193	12	57	Stevens	22	26	..	..
Motley	23	39	14	24	Taboada	91	127	22	22
Oravec	61	207	80	178	Thomson	..	..	3	5
O'Sullivan	5	13	16	29	Toche	..	..	2	2
Parker	33	33	..	..	Upjohn	50	50	69	71
Parks	22	22	21	25	Venter	25	46	27	50
Pearcy	102	112	100	107	Webb	17	19	20	20
Peltier	58	226	60	251	Yamada	36	185	..	..
Penhallow	104	188	40	40					
Peter	18	70	39	287		77	5,963		4,936
Reeves	2	2	2	2					

Nova Search: Reports on the Nova Search Program were received during September and October from 7 observers, as follows:

Observer	SEPTEMBER Area	No. Nights	Magn.	OCTOBER Area	No. Nights	Magn.
Adams	39, 40, 57, 58	7	8	39, 40	8	8
	86, 87	5	8	57, 58	5	8
				57, 58, 86, 87	1	7
				86, 87	6	8
Blunck	8, 9, 10	4	6			
Diedrich, DeL.	Dome	1	1	Dome	1	1
	40	1	6	40	2	6
	40	2	4	40	1	4
Diedrich, G.	Dome	1	1	Dome	1	2
	78	1	6	Dome	2	1
	78	2	4	78	2	6
				78	1	5
				78	4	4
Rick	Dome	11	1	Dome	5	1
	18	13	4	18	6	4
	18	1	3	63	5	4
	63	14	4	65	4	4
				65	1	3
Rosebrugh	Dome	5	3	Dome	7	3
	1	4	4	1, 34	3	4
	34	2	4			
Smith, F. W.	3, 4	5	6	3, 4	5	6

November 15, 1950

Comet Notes

By G. VAN BIESBROECK

This year's crop of new comets still stands at only one, namely 1950 *b* (Minkowski). It is now behind the sun and will pass perihelion next January 15. But already in the latter part of December it will be observable in the morning sky. It is expected to reach a maximum of ninth magnitude in March.

Little is to be added concerning the very faint periodic comets mentioned last

month, which remain in reach of large telescopes for some time. The most recently found 1950 *e* (PERIODIC ENCKE) is the only one gaining in brightness. Last night it was recorded here as a diffuse round coma at least a minute of arc in diameter. The total brightness was hardly equivalent to a 17th magnitude star.

Williams Bay, Wisconsin, Nov. 13, 1950.

General Notes

Dr. Arthur D. Cole, formerly of the Leander McCormick Observatory of the University of Virginia, has been appointed instructor in astronomy at the Washburn Observatory of the University of Wisconsin. He succeeds Harold L. Johnson, who resigned to accept an appointment at Yerkes Observatory.

Professor Bengt Strömgren, Director of the University of Copenhagen Observatory, Denmark, has accepted, effective January 1, 1951, an appointment with the University of Chicago as a Professor of Astronomy. He will also be the Chairman of the Department of Astronomy and Astrophysics and the Director of the Yerkes and the McDonald Observatories. It will be recalled that Professor Strömgren was recently awarded by the Vice-Chancellors of the Universities of Denmark the first Augustinus Prize (valued at 50,000 Danish Crowns) for his accomplishments in Astronomy and Astrophysics.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on Friday, November 17, in the Lecture Hall of the Franklin Institute. In place of a lecture for this meeting, the new forty-minute sound movie "The Story of Palomar" was shown.

New Cosmological Theory

In *Time* for November 20, 1950, a new cosmological theory by Mr. Fred Hoyle and Mr. Raymond Arthur Lyttleton is set forth at length. These two men are teachers of mathematics at Cambridge University. They began working on this theory before World War II, were obliged to stop work on it during the war, because of other duties, and now have resumed their investigations. The story in *Time* is accompanied with a number of illustrations.

Provisional Sunspot Numbers for October, 1950*

1	41	11	68	21	27
2	41	12	88	22	20
3	41	13	75	23	22
4	50	14	72	24	32
5	50	15	106	25	30
6	45	16	103	26	37
7	54	17	99	27	51
8	78	18	74	28	55
9	84	19	50	29	95
10	79	20	48	30	107
				31	74

Mean Value for October
R = 61.2

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

The Cleveland Astronomical Society

The first meeting of the 1950-51 season of the Cleveland Astronomical Society was held Friday evening, October 20, at the Warner and Swasey Observatory, Case Institute of Technology. Dr. Giorgio Abetti, of the Astrophysical Observatory, Florence, Italy, was the speaker. His topic was "Galileo the Astronomer."

Dr. Abetti gave an extremely interesting lecture to a capacity audience. Interesting sidelights on Galileo's early life were presented and his astronomical discoveries were carefully traced from the time he built his first telescope in 1609 to the time he became blind in 1638.

Among some of the most interesting accounts presented by the speaker were Galileo's observations, and interpretations of the four bright moons of Jupiter, the rings of Saturn, the phases and varying size of Venus, and the motion of the sunspots on the disc of the sun.

The four starlike points of light associated with Jupiter, Galileo correctly interpreted as moons revolving around the planet because of their peculiar motions. Observing Saturn when the earth was in the plane of its rings he interpreted, incorrectly the bright spots on each side as two moons. When they did not move he was puzzled but when the rings began to spread out he drew them as appendages but didn't know what they meant. The phases of Venus and its corresponding variation in apparent diameter strengthened Galileo's belief that the sun was in the center as required by the Copernican system. The movements of the sun spots he correctly interpreted as being due to the rotation of the sun on an axis.

The lecture was illustrated with lantern slides, some showing copies of Galileo's original notes and drawings. Dr. Abetti graciously answered questions asked by the audience following the lecture.

Henry F. Donner, *Recording Secretary.*
Western Reserve University, Cleveland 6, Ohio.

The Cleveland Astronomical Society

Dr. S. Chandrasekhar of the Yerkes Observatory addressed the November 10 meeting of the Cleveland Astronomical Society. His topic was "Interstellar Clouds."

Dr. Chandrasekhar gave three lines of evidence that interstellar matter exists among the 100 billion stars that make up our disc-shaped galaxy and that such matter probably constitutes 50% of the total matter in our galactic system. He mentioned that stars in certain directions and distances appear redder than they should be according to spectrographic evidence. The light from these stars has been scattered, according to wave length, by intervening matter irregularly distributed in clouds.

Diffuse nebulae, both luminous and dark, are also indications of interstellar matter. Wherever a bright star happens to be within or near a cloud of this matter it is illuminated to form a luminous, gaseous nebula. If the star is an extremely hot star the illumination is largely fluorescent indicating gases. If the star is cooler than a certain type the illumination is due to scattered starlight indicating solid particles. The clouds must therefore be made up of both gases and solid particles.

Dark lines have been found in the spectra of distant stars which are not characteristic of the stars and do not belong to them. They are due to interstellar gases. Usually the more distant the star the more intense these lines are. Some are split into several components indicating clouds irregularly scattered and moving at various velocities.

Dr. Chandrasekhar said the reddening of stars, the diffuse nebulae, and the dark spectral lines are all due to the same matter scattered through interstellar space. The material is composed of both gas and solid particles ranging from 10^{-5} cm to 10^{-4} cm in size and in many places concentrated into clouds. He speculated that these clouds may be formed by eddies due to turbulence which results from motion in a large medium.

The speaker said that starlight becomes plane polarized in its passage through space. This must also be due to interstellar matter, but means that the particles are not spherical in shape but elongated or needle-like and all oriented in the same direction. Different areas in the sky show different magnitudes and directions of polarization which indicate clouds of different orientation. The speaker suggested that the orientation might be due to a magnetic field developed in the cloud and speculated on how such a field might be developed.

This very interesting lecture to a capacity audience closed with a question period.

On the following afternoon, November 11, Dr. Chandrasekhar lectured to the Neighborhood Astronomers on "Stellar Statistics," also at the Warner and Swasey Observatory.

HENRY F. DONNER, *Recording Secretary.*

Western Reserve University, Cleveland 6, Ohio.

Tabellen Zur Heliographischen Ortsbestimmung, by M. Waldmeier. (Published by Birkhäuser, Basel, Switzerland. 14 Swiss Franks.)

This volume, of 62 pages, as its name implies, contains tables for determining accurate positions of observed phenomena on the sun's surface. The author feels that such tables are needed because of the greater attention paid to solar research in recent years, and because of the possible bearing of solar phenomena upon terrestrial phenomena related, for example, to meteorology and broadcasting. With the tables are found charts and detailed instructions as to their use. The tables will serve a most useful purpose in cases to which they are applicable.

C.H.G.

NOTE: The editor will be in attendance at the meetings of the American Astronomical Society in Haverford, Pennsylvania, at the time when the January issue would normally be printed. Therefore, the mailing of the January issue will be delayed a week or ten days.